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EVOLUTION AND CONSCIOUSNESS.[1]

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There is no problem of present-day science of more vital importance to the psychologist than the problem of determining the relation of consciousness to the general process of organic evolution. This problem touches the very existence of psychology. The physiologists and the biologists have long been contending that they can give an adequate scientific account of human life without using the term consciousness or any of its synonyms, and their contentions will become convincing unless satisfactory evidences are speedily adduced to show that consciousness is not a mere by-product of organic adaptation. Indeed, there are those who bear the name psychologist who are, in this matter, arrayed on the side of the physiologists and biologists. They tell us that nothing significant is added to the concept of adjustment or the concept of behavior by discussing psychical factors. All behavior is a simple sensory-motor process; those types of conduct which the unscientific man is wont to think of as intelligent and extra-organic are merely complex instincts or at most combinations of reflexes acquired under the stress of external excitations.

I am well aware that it is bold to set oneself in opposition to this tide of biological opinion. One is likely to get himself classified as an uncritical layman when he begins in this day and age to talk about consciousness as of positive importance in the evolutionary process. Or he gets himself suspected of adherence to sentimental dogmas such as moved the early

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critics of Darwin and Spencer. I shall hope, however, to defend my position adequately against the charges of uncritical superficiality and sentimentality. I shall hope to show in strictly objective terms that consciousness is a product of evolution which continues in a higher form the movement which is manifest in all earlier adaptations. I shall hope to show further that as soon as consciousness was fully evolved the d rection of all adaptation was radically modified. Finally, I shall defend the thesis that if any scientific explanation of human life is to be attained that explanation must be based on a thoroughgoing study of consciousness. The social sciences have sought in vain to base themselves on the general doctrine of organic evolution. The processes of human adaptation are different from those of animal adaptation just because human adaptation is determined in character by consciousness.

Let us turn at once to the considerations that justify the theses which I have formulated. The statement on which all students of evolution agree is that there has been a steady increase in the complexity of organisms. It has frequently been pointed out that the use of such terms as progress or improvement is not objectively permissible. The biologist will not say that the more complex organism is better or worse, that the path of evolution is upward or downward. The strength of the captor is good from the captor's point of view, but bad from the point of view of the captive. Complexity on the other hand is a purely objective fact and is not affected by the point of view.

What is the significance of this increase in complexity? The lesson is perfectly clear when we look at the concrete facts. By an increase in complexity the organism attains to an ever-increasing degree of self-sufficience. Take the matter of temperature for example. The simple organism is utterly dependent for its body temperature upon the environment, while the complex organism can maintain within its complex body a standard temperature of its own. The advantage for range of life is obvious. The simple organism cannot move beyond narrow limits while the complex organism with its self-sufficiency in matters of temperature can safely move through wide variations of environmental temperature.

Another striking example of increasing self-sufficiency is furnished by studies of the reproductive processes. In the simple forms of life the offspring is exposed very early to the mercies of the environment. The parent organism has no adequate means of protecting the young. Gradually the parent grows more complex, and in the same degree better able to protect the offspring. There is an increase in the food supply deposited with the egg, and an increase in protective devices. The goal of this line of evolution is reached when the parent becomes sufficiently complex in structure to provide for the elaborate development of the offspring within the parent organism. The whole process of evolution is here seen to lead in the direction of self-sufficiency on the part of the organism. Instead of depending upon the chances of environmental conditions the organism builds up an environment of its own within which its reproductive processes may be brought to a high degree of completion before exposing the product to the external world.

Every organ of the complex animal bears witness to the truth that inner self-sufficiency is the end toward which organic evolution has been progressing. There are organs for the storing of energy so that the individual shall be relatively free from the necessity of securing immediate nutrition. There are organs for the secretions of chemical reagents which shall convert the raw material used as food into proper ingredients for the building up of body tissues. Organisms have always exhibited in their higher forms organs of mobility which make them free to move at their own initiative.

In all these cases the obvious significance of increasing complexity is increasing autonomy of the individual. The process of evolution has resulted in a more stable set of inner conditions which make it possible for the vital processes to go on without interruption or hazard from fluctuations in the outer world.

The formula which has usually been employed in describing the evolutionary process is the formula of adaptation to the environment. This formula has given great prominence to the environment and one gets the impression from reading much of the current writing that the term adaptation has been interpreted

to mean growing approach to the environment on the part of evolving organisms. It is not true, however, that individuals are growing more and more like the environment. On the contrary the higher the individual the less its organism resembles the environment. The fish is less like the water in which it lives than is the medusa. The fish is more complex, more independent of external conditions, more clearly differentiated from its surroundings. The principle of self-sufficiency is seen in such examples to be a much more exact description of the evolutionary process than is any principle which can be misinterpreted to mean conformity to the environment. It is strictly in keeping with the facts to say that animal evolution has been one continual progress away from the environment. The struggle for existence is a struggle to establish and maintain individuality. Let it be noted that this statement does not for a moment deny that organisms arose out of the environment or that they continue to draw from the environment their subsistence. What is stated is that organisms are drawn out of the environment, that is, they are in ever-increasing degree differentiated from the environment during their more and more complete evolution.

Such considerations as these prepare us to understand the importance of consciousness. Consciousness is a function which promotes self-sufficiency by literally taking up the environment into the individual and there remoulding the absorbed environment in conformity to individual needs. Consciousness is an inner world where the motives of individual self-sufficiency are dominant. When in this inner world the relations between elements of the environment are adjusted in such a way as to conform to private demands, then the individual is in a position to go forward in an aggressive way with an attack on the outer material world. This outer world may now itself be remodeled to conform to the inner pattern. The self-sufficiency of the conscious being thus becomes an accomplished fact through ultimate subjugation of the environment. Consciousness is no less a fact than the inner standard temperature of the body. In both cases evolution has prepared an inner set of conditions in which life is more advantageously promoted. In the case of consciousness, however, the evolutionary process has gone so

far as to produce a function which changes the whole balance of the world and puts the environment in a very real sense of the word under the control of the inner organized being.

These general characterizations of consciousness can be made clearer by following in brief outline the salient steps in the evolutionary process. The primitive function of irritability out of which consciousness was evolved consisted at first in a general internal commotion whenever external energy acted upon the organism. Heat, for example, heightened the inner molecular activity of the protoplasm, likewise light and the grosser forms of energy. Gradually these inner commotions became differentiated. The now differentiated type of inner commotion began to reflect in some measure the relation between the individual and the environment. If the individual did not gain in power of self-preservation through the particular form of inner commotion, there was a tendency for that particular type of inner commotion to cease. If, on the other hand, the inner commotion meant greater ease and certainty of self-preservation, it was preserved and elaborated.

While differentiation was going on, the various differentiated forms of irritability began to undergo an internal combination. When light stimulation set up one form of commotion and contact set up another, the two protoplasmic commotions underwent within the individual a combination. This combination was a unique event. It was a combination governed by the laws of protoplasmic behavior. Light sensation and contact sensations were combined within a single organism, not for the purposes of bringing together light and molar energy but for the purpose of promoting a new complex vital function, an inner function which should serve the ends of self-sufficiency. To describe such a combination as a mere adaptation of the individual to the environment is to fail in the apprehension of the real evolutionary significance of the change. The individual is becoming internally integrated and as an integrated individual presents to the environment a more and more highly individuated front. The individual is working out the problems of its life within itself. Even its relations to the elements of its environment are being worked out within itself.

The integration of inner processes of irritability become more complete when in addition to integrating commotions aroused by forms of external energy momentarily present, the inner organism began to contribute through its powers of retention commotions brought over from past stimulations and past inner combinations. These inner complications make strikingly clear the trend of evolution. The organism is not becoming like its surroundings, nor is it remaining dependent upon environmental initiative. The organism is not becoming subject to external laws of energy. It is rather evolving in a direction which leads it further and further away from the external world. Its inner processes are becoming more complex, more and more independent of external energy, more highly individuated. The result of all this evolution is that the individual comes ultimately to contain an inner world governed by laws of combination which are wholly different from the laws of the outer world.

Some students of science profess to be mystified by the assertion that the inner world produced by evolution is fundamentally different from the outer world in its character and in its laws. These persons should study their biology a little more closely. They will find that from the first, evolution has been pointing away from the physical world and its laws toward a self-sufficient individual governed by inner laws.

When the individual reaches a stage where inner combinations can be freely worked out without dependence upon the environment there is likely to appear an excessive exercise of this inner power. When a child realizes that in his inner conscious world relations can be easily readjusted he indulges in unlimited recombinations. The race too exhibits in its myths the same freedom in making up recombinations. In both the child and the race the exercise of powers of recombination for the mere pleasure of the exercise has a secondary effect. Consciousness is, by this exercise, more fully developed and while the utility of such early mental processes is not great, yet the stability of consciousness as an inner function increases and is ultimately assured through exercise. We shall never grasp the significance of some of the earlier periods of human evolution

until we recognize the long effort which was required to establish the function of mere recombination in the conscious life. When the method of recombination was fully mastered, then and then only was the race prepared to refine the function by a critical sifting of its products.

After the inner combinations which we have described came to some degree of perfection the last step of evolution was taken. The evolved organism began to strive for a reorganization of the environment in conformity to its own imaginings. In these imaginings the world had been put together in such a way as to make it appropriate to the individual's inner needs. If now the outer world could be made to conform to the demands of the inner world, if the environment could be remoulded on the pattern of inner desires, then the world would be a more favorable environment. The history of this effort to fit the outer world to an inner pattern is the history of human struggle with the environment. The savage pictured the ease of a land full of good things and free from enemies. At first he adopted the simplest expedient of realizing this dream. He thought of such a land as lying somewhere ready made and he wandered about ever hoping to find the world of ease. Finally, he came to see that he must make that world by improving what was at hand and by removing all that was inimical. Again, the savage pictured a being like himself behind the wind and rain and he adopted devices in dealing with wind and rain which would have conciliated himself. He was baffled beyond degree when his efforts of sacrifice and worship were of limited avail. He went on, however, building up more and more elaborate imaginings until finally the weight of his own system brought him to revision. After revision he began in new ways to make the world conform to his inner desires. By a long series of trials he arrived at methods which are fairly successful. The period of mere subjective imaginings was thus justified by later periods of more useful readjustments in consciousness. The imaged readjustments are now capable of being employed with success in bringing the outer world into conformity with the inner world.

Consciousness is seen in such examples as these to be a mediating function in which the opposition between environ-

mental forces and personal needs is overcome through a dual process of taking the environment into the individual and there working it over and over until it assumes a form in which the environment may be used to the advantage of the individual while at the same time the individual conforms to the requirements of the environment which he absorbed.

The importance of consciousness in the evolutionary processes is that it solves the age-long opposition of individual and environment in a new way, giving to both a unique recognition and to the individual a supremacy over external conditions which none of his other functions ever permitted. Contrast consciousness with the nutritive function. Through digestion much material is taken into the organism and is used to build up animal tissue, but there is no reflex influence on the outer world. The environment is not made, through the process of digestion, more digestible for the future. When, however, we discover through consciousness how to use the world for the ends of individual life, the environment itself can be modified so that it will from that time on be different in its relation to the evolved individual.

Let us take another illustration and work it out in somewhat greater detail in order to show the applicability of this concept of consciousness in the sphere of the social sciences. Primitive man found his first tools in the rough ol jects of nature. The sharp thorn or bone, the heavy root or branch all offered themselves to his hand as means of better meeting the demands of life. We need not pause to discuss fully the evidence of high evolution which appears in the fact that man apprehended the value of these rough objects as the other animals had not been able to apprehend it. Man saw in his more efficient conscious world the relation of the heavy club to his enemy, the relation of the sharp thorn to the object that he would rend. This in itself was sufficient evidence that the evolution of consciousness had served an important end in the improvement of individual life. Passing over the first stages of tool-consciousness, however, let us concentrate attention on the fact that as soon as primitive man took these natural implements in his hand he began to make in his inner conscious world comparisons of the

various tools which he knew. He began to recognize a smooth handle and a rough edge as advantageous. The result was a better selection of weapons and tools and the beginnings of the art of smoothing the handles and sharpening the edges of the instrument. First nature, and then a modification of nature. The next step came when man saw that these natural forms could be improved by using more durable materials. He began to work in stone. At first he copied slavishly nature's patterns and then he made shapes that nature had suggested but never perfected. Now he began to recognize that the whole matter of available materials was worth considering. The more permanent the tool and the more plastic the material the higher the advantage to which he could attain. So he took some of the most pliable and most accessible minerals and he made of them shapes that nature had taught him at first but which he had now so far refined that the credit for the present form belonged to him rather than to the world of nature. Through this schooling of his powers he began to rise to the level where forms and materials were sufficiently mastered so that he could contemplate the underlying mechanical principles which these contrivances exhibited. The analysis of the tool now reached the point where man's working over of the situation in his world of consciousness was of infinitely greater importance for even the external world than were the original forms presented to his senses. As soon as man learned to extract the principles on which his tools were constructed he was master of the environment. He now moulded materials, following his ideas, into forms and combinations that never under any chance could have come into the world through the mere operation of physical forces. For these forms a world was necessary in which images could first be worked over into new combinations which should in turn supply the pattern for a reworking of external reality. The conquest of the environment through the organization of conscious images is here illustrated so clearly that it is difficult to see how any complete history of art or industry could be written without a thoroughgoing analysis of the conscious processes which lie back of man's efforts and explain the stages through which he passed in his conquest of his environment.

Thus far I have emphasized the importance of consciousness as a means toward the end of conquering the environment. There is however another phase of the matter which calls for our attention before we shall have a complete account of the significance of consciousness for the explanation of human life. There are certain human functions which grow up as supports to consciousness. These functions are not directly related to the physical environment and would never have been perfected at a level of life where mere preservation of individual existence is the chief end of animal endeavor. These supporting or secondary functions serve the purpose of self-preservation only indirectly through consciousness. Chief among such functions is language.

Thanks to the recent studies of Wundt and others we know much regarding the functions of language. It originates as a mode of emotional expression, purely individualistic in its importance. Gradually it takes on through imitation a social character, and, finally, when society comes to be made up of beings capable of holding ideas in consciousness, language becomes a means of refining and exchanging ideas. Language never was a useful function in the direct struggle with the physical world. The man who can shout the loudest is in no wise thereby aided in enduring the hardships of cold and privation. Shouting is useful for a totally different type of adaptation. The shouter is a very valuable link in social adaptations and social adaptations are valuable in that they refine consciousness and make for more elaborate organizations of the human forces which shall conquer nature. This is what was meant when it was pointed out a few moments ago that language is a secondary or indirect factor in the struggle for existence.

When language is evolved as a secondary function supporting consciousness in its operations, there arises a new realm of fact. I know of no more vivid way of putting the matter than to say that man lives primarily in the world of words. In this world of words he carries out most of his adjustments. He feels the force of the physical environment now and then when he comes into contact with its harsh demands, but for the most part he works over and over with all his energies words and conscious relations.

If we add to our consideration of oral languge the consideration of other devices such as writing and coins and bills of exchange whereby we support conscious operations as they deal with the world of physical facts at long range, we see how man has built himself a special world in which he moves. This special world is the most unique product of evolution and it is also the most effective device which has ever been produced for subjugating the physical environment to human needs. How any student of the world of human life could be content to study this life by means of a formula borrowed from the realm of animal evolution, passes my understanding. Man lives in a world of language, of indirect conscious modes of attack upon his physical environment. Man spends his chief energies developing indirect methods of attacking nature. He no longer cultivates new strength with which to pass through floods. He develops rather a science of engineering and indirect mechanical devices which shall raise him into a world where there are no floods. And yet we find our students of human life solemnly talking about the biological conception of society and the parallelism between society and the lower organisms. The fact is that the science of human life needs a formula derived from a study of the relation of consciousness to the struggle for self-sufficiency.

How completely the evolution of consciousness has removed human life from the level of animal modes of contact with the world is seen by the contemplation of human art. We derive from art the kind of satisfaction which comes from catching a glimpse into the conscious life of a fellow being. Art carries over from man to man the inner possibilities of rearranging the physical environment. A painting for example lets us see how the artist selected from the images offered to him by the outer world, and how he grouped these images for the purposes of his own conscious satisfaction. A painting is of value as a means of arousing our powers of conscious rearrangement of the world. Art is, from the purely biological point of view, of no immediate adaptive value, and yet it is recognized as one of the highest achievements of human life. What is needed here is just such an extension of the biological formula as we have all along been

suggesting. Organic evolution operated to establish self-sufficiency in the animal until finally an animal was produced in whom inner conscious processes outweighed all others in importance. These inner processes are important because they make possible the most complete readjustment of the environment. The inner processes are also highly significant because they give rise to a new world, the world of language and art which supports and fosters the further evolution of consciousness until there is established through consciousness a new system of life.

Perhaps the view which I have been defending can be made clearer by contrasting it sharply with such a view as that recently expressed by MacDougall in his Social Psychology. MacDougall it will be remembered deplores the strongly intellectualistic trend of our psychology and finds in this trend the explanation of the fact that the social sciences have not been able to use psychology as they should. The social sciences deal with men in action and the springs of action are the instincts. Emotion rather than cognition is the conscious accompaniment of instinctive behavior; let us accordingly rewrite our psychologies so that the students of social science may use them. In this rewritten form let us treat the instincts and the emotions as the chief factors in determining human evolution. I am sure I have not misrepresented MacDougall in this summary for in common with the rest of you I have been through the dreary pages of description in which he discusses the various emotions, and I have tried in vain to find in those pages the principles which would explain human civilization. The fact is that human civilization has not been toward instincts and emotions, but away from them. Language has evolved out of instinct, if you please, but it is so far from instinct in its present character that it has taken long generations of acute scholarship to show the process of ascent. Language is as intellectualistic a function as can be found in the world. Again take our material arts. Are buildings the outgrowths of the instinct for warmth or are manufacturing plants the products of hunger? Is commerce the outcome of the instinct of acquisitiveness? I think MacDougall's diagnosis of the difficulty with the social sciences

is better as he writes it in his preface and introduction than as he writes it in the body of his book. I agree with him when he holds that human life can be explained only by psychological principles. I do not agree with him when he minimizes intellect as distinguished from instinct. I do not sympathize with him at all in his attempt to bring human action back to the fundamental formula of all animal behavior. Human behavior is not aimed at maintaining oneself within the environment, it is aimed rather at complete remoulding of the whole environment, and the chief instrument in this process of remoulding is intellectual comparison and deliberation, not emotion. Note that I do not deny for a moment that human life is full of exhibitions of instinct and emotion. I do not deny that civilization repeatedly comes back to animal life instincts, but I find in these lapses into instinctive behavior only the necessary background of human evolution, not its typical modes of progress. Whoever would understand our buildings and our commerce and our language and our arts must study human intellect rather than human emotions.

A second view which I shall touch upon is that of Darwin. Darwin evidently felt, as did his critics, that the formula of natural selection is not adequate to explain human life. Man has not only been selected as superior in his equipment for the race of life, but he has been set apart as different. So Darwin took up the task of showing how this difference came about. He noted that many animals develop through sexual selection, powers which are ornamental and socially useful but would never be preserved merely through contact with the physical world. So he wrote his Descent of Man to show the importance of sexual selection. I think no reader of Darwin's writings ever feels that the author himself was enthusiastic regarding this solution of his problem. Human sexual selection could hardly have accounted for even the primitive feats of bravery which make up the legends of our heroes. Certainly the society of today has not grown out of the demands of sexual selection. The control of all social relations is under principles, not of sexual efficiency, but of moral and intellectual propriety. Indeed, the type of social organization which we

have is not the source of human superiority. It is rather the expression of human superiority. Man has not developed the most compact sexual society, — such organization is exhibited in high perfection even in the lower animal world. Man has made his way in the world by some means which first made him master of the environment. The conservation of property has been quite as strong and intelligent a motive in the organization of society as any motive that can be described. Darwin was undoubtedly in line with all our modern thinking when he felt the necessity of a special formula for human evolution, but he hardly satisfied the demand which he felt. The breach between animal life and human life is much too great to be spanned by any single form of selection. The fact is that the method and end and character of human life are all different from those described in any formula of organic selection.

I should not want to be misunderstood as assenting to their views, but I confess I always have sympathy with those critics of the early writers on evolution who stood according to their light for the time-honored separateness of man from the rest of the world. For generations human thought had regarded the animal world as another world, and here came men who would impose on fish, bird, mammal and man the same stamp. I believe the identification was overhasty. I believe that we have suffered in our later studies of man through a shortsightedness born of the biological discovery that our antecedents are those in which consciousness played but a small part. I believe we need to work further on this problem of evolution until we see that in its consummation organic evolution passes into a form of adjustment in which the inner world with its conscious pattern for changes in the outer world is more important than any form of objective selection which can be discovered.

The evidences which I have presented up to this point justify, I believe, the conclusion that consciousness continues and carries to a higher level the process of differentiation of the individual from his environment which has been going on throughout all organic evolution. The examples discussed show also, I believe, that consciousness is the means of changing very materially the significance of the environment to the individual.

At all of the lower stages of life the environment is dominant and the individual survives chiefly by withdrawing into itself. With the appearance of consciousness, however, the balance is changed. The individual takes up the environment and begins to make it over so as to conform to patterns developed within. The result is the familiar fact which has often been pointed out by the anthropologists that man has never in his history undergone any changes in his bodily organs which would in the slightest measure justify us in attempting to explain in organic terms the recent or even the remoter advances in civilization.

These conclusions are in no wise jeopardized by the difficulties which arise the moment we ask how consciousness operates in detail in bringing about these results. Indeed, I have put off the discussion of several questions which I am sure must have arisen in your minds because I have recognized that there will be divergencies of opinion in regard to these details. I have not meant to evade the difficulties and I turn now to the examination of several of them. Let me reiterate, however, the statement that the major facts are not involved. That consciousness has furnished a turning point in evolution may be, and is, as I have shown, true, even though we may have some difficulty in making that fact cohere with our theories of consciousness. That consciousness is a factor to be recognized in the study of man's position in the animal world, that consciousness is a factor which must be studied in all the social sciences, are facts which must, indeed, be properly set forth in our psychologies, but which continue to be facts of no small moment to the world and to science even while we are rewriting our psychologies to fit these facts.

One of the first questions on which we must be clear is the question whether consciousness is a cause of events in the world. I have no slightest hesitation in taking a position on this question and perhaps it will be well to state that position first and defend it later. I hold that consciousness is a cause of events in the physical world. The difficulty which many have experienced in coming to a conclusion in this matter grows, I believe, out of a failure to grasp the significance of the evolutionary concept. I have elsewhere used the analogy of life to

clear up this difficulty. When one looks backward and asks where life came from he finds himself dealing with material particles which have come into a certain combination. To the physiological chemist this backward view is the natural one. Life is nothing but the result of the combination of carbon with oxygen, hydrogen and other elements. But now let us look forward and ask about the world of tomorrow. Tomorrow we shall find new organic combinations and these will not be due merely to the fact that carbon and hydrogen and oxygen existed today. The organic compounds of tomorrow are dependent on organic compounds of today. One important cause of tomorrow's life phenomena must be sought in the fact that life is here today. We are not here concerned in going back to first causes. Where life came from in the first instance I do not pretend to discuss. It is here now and any adequate explanation of tomorrow involves the existing life of to-day. The physiological chemist may insist on our going back to carbon and the rest and I should have no objection to going with him the full road. But if I go back with him he must come in my direction with me. Carbon enters into this and this compound and from this instant forward it has in the world a unique significance. It is a different kind of a cause from that which it was before it entered into the compound.

Let me reinforce this analogy of life, by the analogy of individuality. An individual can be resolved into a great variety of elements. The individual is what he is because of these elements. If one looks backward and asks for the cause of this individual he is taking a perfectly legitimate view of causation and is quite in his rights in saying that he has in the elements of the individual an adequate account. But again let us look forward. The individual is a center of future influences and the world takes its course tomorrow because the individual did this and that. What is there wrong about the statement that the individual causes certain results? Suppose that the student of atomic structure objected to the work of the physiological chemist an the ground that carbon is no reality but merely a compact bundle of ions. Suppose that our physiological chemist were forced to say carbon is merely a

by-product in the real process of compounding ions. Carbon is an epiphenomenon; its existence is a very doubtful scientific assumption. What if we should insist that the term carbon confuses those of us who deal with ions? We do not deny on the whole that carbon exists, but do not let it turn up in serious literature because it reminds us of the old false notions about the simplicity of the atom. Of course, our physiological chemist would resent this. Why should we who deal with individual differences and other facts regarding human life be timid in asserting our scientific rights? A human being may be a composite organism made up of senses and motor functions and what not. He may even be an unstable compound as contrasted with what we now think about carbon, but every rational consideration of society must be based on a study of individuals. We shall get nowhere in our study of society if we wait for the physiological chemists to supply us with causes of social behavior. If we cannot have their kind of causal concept we should hasten to get one of our own. Their causal concept looks backward to elements, ours should look forward from productive organizations.

I have used individuality as my stalking-horse. If individuality is admitted to be important to science I am quite content to rest the case of consciousness. Consciousness is the essential fact in human life as I have attempted to show. What man does with his environment depends upon consciousness. That phase of individuality which is important enough to change the type of evolution certainly cannot be described as nonexistent or as merely resolvable into its elements.

I think the difficulty in the past has been that we have been dominated by the physicist's notion of cause. With a physicist a cause must be a center of influence equal in importance whether one looks backward or forward. Causes must therefore be constant in number like the elements of matter and the amount of energy in the world. The doctrine of evolution opens the way for a wholly different view of causation. Cause ought to be definable in terms which shall make of life, not a new force, not an increment in the energy of the world, but a sphere of existence, a center of reorganization. Certainly the world is

different because life now flourishes here. The same is true of consciousness. It is not some new fact parallel with heat and electricity and gravity. It is a new sphere of adjustments. The world moves in new lines because this new sphere has been evolved. We cannot put it out of the world because of our own confusion as to how it operates. We cannot understand society by ignoring it. We cannot protect ourselves against the charge of scientific incompleteness in our account of the world by saying that consciousness is not a cause like electricity, hence it is no cause at all. I never hear a physiologist or a biologist contending that there is no possibility of a science of consciousness without wondering how the historian of scientific myths in some future generation will be puzzled by our present-day timidity regarding the causal character of consciousness. I conclude, therefore, as I began by saying that I have never found any confusion growing out of the conception that consciousness causes changes in the world. I have, on the other hand, seen much time and energy misspent in describing consciousness in timid terms which make it difficult to show its value for social science or for any other science.

A second question carries us further into detail. How does consciousness operate in controlling bodily activity? I dare say that all of us who are engaged in the study of psychological problems would agree that the most important particular problem of today is the problem of the relation of consciousness and bodily movement. Here again I believe that the evolutionary concept is the one which will clear up many of our difficulties. Let it be remembered that for a long period organic evolution was perfecting a sensory-motor mechanism which was not dominated by any highly centralized organ such as the cerebrum. There was no higher nervous center where elaborate combinations of impulses were possible. When now the inner organization reached a stage of complexity such that inner recombinations were possible and consciousness in all of its importance appeared and began to turn the scale in the struggle with the environment, there still remained a large number of processes and organizations which belonged to the earlier simpler uncentralized stage of evolution. We are in the habit of recog-

nizing this fact in the statement that consciousness does not control all of our acts. Put in other terms this statement can be made as follows. There are many of our acts which are not dependent for their character and influence upon higher processes of comparison, memory and self-control. This internal separation of the individual into higher and lower functions has given color to all of our ideas about the nature of behavior. Every individual is trying to develop inner coherency. The individual with his different levels has been so acutely aware of his effort to work out this coherency that he has had all kinds of views with regard to the higher self and the lower self. The antithesis carried man so far that he lost sight at first of the utility of his higher self as a center of functional adaptations and he grew accustomed to describing his conscious life as pure and unrelated to practical conduct. Later he was led to change his views regarding his own nature very radically. When he saw the significance of his conscious life in the evolutionary process he began to identify all his activities with sensory-motor processes which he had all along recognized as practical and thus arrived at the grotesque conclusion that he must be treated as just like the lower animals.

We are in a fortunate period of reconstruction when the relation of consciousness to behavior is being considered on the basis of elaborate objective studies of the facts. It would not be in place here to attempt a critical review of these studies. It is enough for our present purposes to point out that the evolution of consciousness has been so intimately related to the evolution of the higher forms of behavior that the progress of human intellection can be traced in the record of behavior. The science of psychology will not find itself until it turns away from impressions and sensory details and recognizes that the inner processes of conscious organization so transform sensory elements that there is in sensation little of value for the student of consciousness. Behavior on the other hand is the expression and end of all inner organization. To study behavior more completely is therefore the most urgent of our problems, — in a very important sense it is our chief problem. When we know the evolution of consciousness we shall find the relation between consciousness

and behavior solving itself as two phases of the same single process of adaptation.

In the third place, I believe the evolutionary principles which we have been discussing reveal the limitations of structural psychology. The structural psychologist shuts himself up within consciousness as if the conscious world had within itself its own origin and ends. He makes the enumeration of forms his only function. In assuming that consciousness is a world apart, the structural psychologist is following the natural trend of experience which, as we have seen above, tends to emphasize the separateness of consciousness from behavior. The structuralist does not see the significance of the effect which is produced in human society through the evolution of a sphere of life in which rearrangements of the world may be worked out. The structuralist makes no contribution to social science, for society is not organized on the separate elements of conscious experience, but upon the effects produced through intelligent behavior upon the environment. Consciousness as a static fact to be dissected loses its whole significance, for consciousness like life is a type of functioning. Functional psychology as contrasted with structural psychology opens up the whole world of effects, both in behavior and in transformations of the physical environment. Functional psychology makes clear the relation of consciousness to other functions. How anyone can be satisfied to enumerate sensations when the rich possibilities of explaining the relation of sensation to perception, to judgment, and to behavior are equally open problems, I confess I cannot understand. How one can talk about a sphere of psychical causality, and can see in this cut-off world a legitimate sphere for science, I am at a loss to comprehend. For my own part I am persuaded that the science of psychology will never be accepted as contributing lessons worth the attention of men until this science shows the way in which consciousness has by its evolution transformed life.

Finally, I believe that the applications of psychology to practical problems will be fully worked out only when we recognize the importance of consciousness in evolution. The relation of rationality to self-control, the relation of intellect to

the arts and industries which characterize civilization, the relation of thought to the growth of institutions, these are practical problems and at the same time psychological problems. We have been in some doubt in the past as to whether society is based on instincts or on ideas. We have talked about our institutions as intelligent, but studied them as if they were mechanical. Our whole treatment of human life has been biological rather than psychological. I believe that the period of biologizing human life is over. We shall lose none of the advantages gained from a study of reflexes and instincts if we recognize that these are primitive phases of human organization and less significant than the higher conscious phases. We shall understand the productive forms of activity better if we recognize them as related to intelligence which is the consummate product of evolution. If time permitted one could carry out this reference to applications in great detail. I have referred to the devolopment of tools. Think of the way in which modern industry exhibits in its use of commerical paper the growth of the power of conscious abstraction. Think of how early barter exemplifies the concrete, perceptual character of savage intelligence. Think of the growth of the fine arts and note how it illustrates the growth of the power to distinguish more clearly the elements of experience and combine them into more elaborate wholes. Think of the development of science in the modern world as a sudden fruition of intelligence which had been in training for long generations. In short, take any phase of human life and see how it becomes suggestive material to the student of evolutionary psychology. Note from the other side how utterly incomplete the study of these phases of life would be and would remain with consciousness left out. I believe we are on the eve of a newer psychology than any which we have known. This new type of psychology will not be unfriendly to biology for it will study evolution, but it will not be dependent on biology for its formulas. Psychology will boldly assert its right to existence as the science which deals in a broad way with the evolutionary processes by which consciousness arose and through which the trend of life has been changed from organic adaptation to intelligent conquest.

THE NATURE AND CAUSATION OF THE GALVANIC PHENOMENON.

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PART I.

THE NATURE OF THE GALVANIC PHENOMENON.

I.

The purpose of our present paper is to establish rigidly the fact of the presence of galvanometric deflections under the influence of psycho-physiological processes and to investigate the nature, causation and conditions under which such deflections become manifested. It is by no means an easy matter to disentangle the conditions, physical, physiological and psychological, under which galvanic deflections appear, when an organism becomes subject to external or internal stimulations. Even when the galvanic deflections due to stimulations are established still the nature and causation seem to be beyond our grasp as the factors are numerous, the conditions complicated and the whole subject of the psycho-physiological galvanic deflections appears to be intricate and shrouded in obscurity. Investigators of the subject have declared it to be a difficult one and have been unable, except for a few conjectures, to trace scientifically by means of experimentation the cause of the 'galvanic phenomenon.' We think that our investigation will not only establish the fact of the galvanic phenomenon free from all artefacts, but will also clear the subject of all its inherent obscurities and help to disclose its nature and causation. If may be well to add that the present study is a continuation of the work carried out by Sidis and Kalmus and published in THE PSYCHOLOGICAL REVIEW for September and January, 1908, 1909.

II.

Tarchanov is regarded as one of the first investigators who discovered the interesting fact that psychic states give rise

to galvanometric deflections. According to Tarchanov[1] all psychic processes, sensory, emotional and even purely ideational, such as imagination and calculation, are accompanied by galvanometric variations. He observed large galvanometric deflections apparently brought about not only by sensory stimulations, actual affective states and emotions, but also by the mere memory and representation of such states. Intellectual processes, ideas, images, logical reasoning, memories are sufficient to affect the mirror-galvanometer and give rise to marked deflections. As a result of his investigation, published in a brief preliminary communication, he conjectures that the deflections may be due to secretory changes going on in the epidermis. He is inclined to think that psychic activities affect the secretions of the skin which in their turn produce the marked deflections observed in the mirror-galvanometer. Tarchanov has not followed up his preliminary communication with a detailed study of the phenomena.

Ch. Féré[2] may also be regarded as one of the pioneers who pointed out the presence of galvanic changes under the influence of emotional states. According to this investigator the changes are due to variations of bodily resistance; in other words, Féré seems to think that emotional states lower the electrical resistance of the body. This assumption of lowering of bodily resistance has been uncritically accepted by many investigators. It is accepted even by those who otherwise follow Tarchanov and assume the alleged factor of skin secretions. It is assumed that the galvanic deflections are due to lowering of electrical resistance through the agency of skin secretions produced by psychic activities. The cause of the phenomenon is still regarded as unknown. We shall point out that the sole cause of the obscure factor of resistance is a faulty reasoning and a deficient technique.

A number of investigators such as Sticker,[3] Sommer,[4]

[1] Tarchanov, 'Ueber die galvanische Erscheinungen,' *Pfl. Arch.*, 1890.

[2] Ch. Féré, *Comptes ren. de Soc. de Biologie*, Jan.–March, 1888.

[3] Sticker, 'Ueber Versuche einer objectiven Darstellung von Sensibilitäts-Störungen,' *Wien. klin. Rundschau*, 1897.

[4] Sommer, Beiträge, Wien, 1902.

Sommer and Fürstenau,[1] Veraguth,[2] Jung,[3] Binswanger[4] and others have advanced various views as to the possible causation of what has become known in psychopathological literature as the 'galvanic phenomenon.' Sticker rejects Tarchanov's hypothesis of skin effects and action of sudorific glands as the cause of the observed galvanometric deflections under the influence of psychic states. He advances the hypothesis of circulation, — the galvanic phenomenon is the effect of circulatory changes in the capillary blood vessels, changes induced by psychic states in general and by emotional states in particular. In this respect Sticker agrees with the French investigators who unhesitatingly assume the hypothesis of circulation. The galvanometric perturbations are supposed to be the effect of circulatory disturbances which somehow lower the peripheral and bodily resistance. R. Vigoroux[5] and later A. Vigoroux[6] experimenting on clinical cases reject the view that the lowering of resistance is due to skin secretions; the electrical perturbations are ascribed by them to variations of resistance of blood circulation especially of the capillary blood vessels, variations of electrical resistance in some unknown way, probably by an increase or decrease of the concentration of the blood, brought about by the influence of mental states, especially by emotions.

Recently C. G. Jung, of Zürich, and his collaborators, Peterson[7] and Ricksher,[8] have carried out a series of experiments on a number of sane and insane persons. They confirm the presence of the so-called 'galvanic phenomenon' accompanying the various mental states under observation. They find

[1] Sommer und Fürstenau, 'Die electrische Vorgänge,' *Kl. f. Psych. u. N. Kr.*, B. 1, H. 3, 1906.

[2] Veraguth, 'Das psycho-galvanische Reflex-Phaenomenon,' *Monat. für Psychiatrie und Neurologie*, B. 21, 1906.

[3] Jung, 'On Psychophysical Relations,' *The J. of Abn. Psych.*, Feb., 1907.

[4] Binswanger, 'Ueber das Verhalten des psychogalvanischen Phänomens,' *J. für Psychologie und Neurologie*, B. 10, 1908.

[5] R. Vigoroux, 'Sur la Résistance électrique,' *Le Progrèss Medical*, Jan. 21-Feb. 4, 1888.

[6] A. Vigoroux, 'Etude sur la Résistance électrique,' 1890.

[7] Peterson and Jung, 'Psychophysical Investigations,' *Brain*, V., 30, 1907.

[8] Ricksher and Jung, 'Investigations on the Galvanic Phenomenon,' *The J. of Abn. Psychology*, Vol. II., 5, 1908.

galvanometric perturbations in different forms of mental states. Jung regards the galvanometer as a valuable instrument in the study, analysis and discovery of so-called 'suppressed complexes' otherwise revealed by the so-called 'psycho-analytic method.' Some of the followers of the German school hail the galvanic test as a method in the study of psychopathic diseases in general and of hysterical affections in particular. Even criminology, it is claimed, may derive some benefit from the galvanic test, inasmuch as certain classes of criminals may be detected by means of the galvanic phenomenon.

Jung and his collaborators have not contributed anything to the causation of the galvanic phenomenon, but they are inclined to accept Tarchanov's hypothesis that the galvanometric perturbations are the effect of skin secretions. According to the Zürich investigators mental activities with their accompanying affective states give rise to secretions of the sudorific glands with a consequent lowering of electrical resistance which is the cause of the observed galvanometric perturbations. This conclusion is but a plausible conjecture. They think however that it is quite probable that a number of other factors concur in the causation of the galvanic phenomenon, such as circulatory changes, changes of the central nervous system and especially changes produced by mental activities and their affective states in the sympathetic nervous system. To quote from Jung, "If one applies to a subject tactile, optic or acoustic irritations of a certain strength the galvanometer will indicate an increase in the amount of the current, *i. e.*, a lowering of the electrical resistance of the body."[1] In another place Jung and Peterson say "change in resistance is brought about either by saturation of the epidermis with sweat or by simple filling of the sweat-gland canals or perhaps also by an intracellular stimulation or all of these factors may be associated. The path for the centrifugal stimulation in the sweat-gland system would seem to lie in the sympathetic nervous system. These conclusions," the authors go on to say, "are based on facts at present to hand and are by no means felt as conclusive. On the contrary there are features presented which are as yet quite inexplicable as, for

[1] *Op. cit.*

instance, the gradual diminution of the current in long experiments to almost complete extinction, when our ordinary experience teaches that resistance should be much reduced and the passing current larger and stronger. This may possibly be due to gradual cooling of the skin in contact with the cold copper plates."[1] As we shall see further on these investigators are on a false track, their puzzles and contradictions can be easily solved.

Again Ricksher and Jung write: "The sweat glands seemed to have more influence than any other part in the reduction of the resistance. If the sweat glands were stimulated there would be thousands of liquid connections between the electrodes and tissues and the resistance would be much lowered. Experiments were made by placing the electrodes on different parts of the body and it was found that the reduction in resistance was most marked in those places where the sweat glands were the most numerous. It is well known that sensory stimuli and emotions influence the various organs and glands, heart, lungs, sweat glands, etc. Heat and cold also influence the phenomenon, heat causing a reduction and cold an increase in the resistance. In view of these facts the action of the sweat glands seems to be the most plausible explanation of the changes in resistance."[1] It will be seen from our work that the Zürich school, when discussing the causation of the 'galvanic phenomenon,' has become inextricably entangled in a maze of factors which have but an indirect relation to galvanometric deflections under investigation.

Veraguth has been working assiduously and patiently for a number of years on what he designates 'the psycho-physical galvanic reflex.' He eliminates circulation and he rightly excludes skin effects as causes of the 'reflex,' but he does not arrive at any definite conclusion as to the cause of the galvanic deflections under the influence of sensory and emotional processes. Veraguth thinks that his 'galvanic reflex' is due to variations of body-conductivity or 'Variation des Leitungswiderstandes des Körpers.' He thinks this phenomenon somewhat different from that described by Tarchanov and others. To quote from Veraguth:

[1] *Op. cit.*

"Das psychogalvanische Reflex-phänomen besteht in einer Intensitätsvariation eines elektrischen Stromes der bei der Versuchsanordenung mindestens teilweise aus einer körperfremden in der Stromkreis eingeschalteten Stromquelle entstammt. Es spielt deshalb bei diese Anordnung die Variation des Leitungswiderstandes des Körpers gegen diesen exogenen Strom einer Rolle bei der Variation der Stromintensitäts.

Die Variation geschiet im Sinne der Abnahme der Stromintensität wenn die V.P. im Zustand der Ruhe längere Zeit in der Stromkette eigescholtet bleibt. Durch diese Thatsache stellt sich die 'Ruhekurve' im Gegensatz zu den gewöhnliche bisherige Erfahrungen über anfangliche Variationen des Körperleitungswiderstandes gegen einen durchfliessenden elektrischen Strom.

Die Variation veläuft im einen der Intensitäts-zunahme wenn die V.P. Reizen ausgesetzet wird.

Das Moment der Gefühlsbetonung allein ist es nicht das die Stärke der galv. Reaction bedingt; es kommt auch bei den höheren psychischen Reizen.

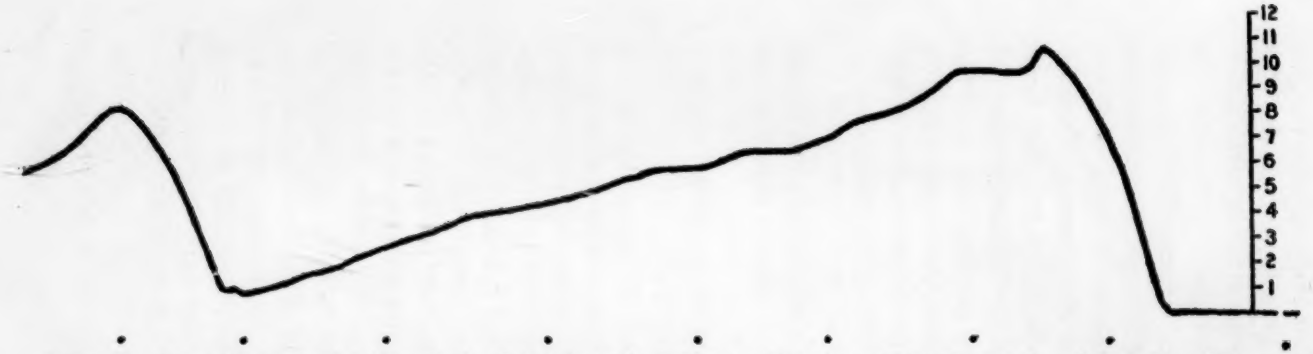
Das galv. Reflexphänomen ist also ein Indicator für Gefühlsbetonung und Actualität des psychischen Reizes.

Uncontrollierbare Variabilitäten des Widerstandes in dem Stromkreisteile ausserhalb des V.P. sind ausgeschlossen; die Tatsache der Variabilität des Leitungswiderstandes des menschlichen Körpers gegen durchfliessenden Strom ist bekannt. Mit ihr haben wir also bei unseren Experimenten mit Körperfremden durchfliessenden Strom zurechnen. Nun zeigt sich aber bezüglich dieses Leitungswiderstand ein auffalender Unterschied zwischen den obigen Resultaten und der gewöhnlichen Erfahrungen aus der Elektrodiagnostik: bei unseren Experimenten nimmt wenn keine Reize eintreten die Stromstarke stätig ab, nicht, wie wir gewohnt sind zu beobachten der Widerstand."[1]

Veraguth's 'phenomenon' is an artefact. The 'Ruhecurve' which he regards as almost paradoxical is an artefact. The gradual diminution of the deflection, when no stimulations are given, is due to involuntary gradual relaxation of the grip on the nickel-plated electrodes used by him in his experiments. This can be shown by the following photographic curves:[2]

[1] *Op. cit.*

[2] The curves should be read from right to left.



CURVE I. Two cells in circuit; also shunt, nickel electrodes held by subject in each hand. Hands relax slowly. The curve slopes gradually. Intervals are indicated by the points under the curves and show minutes. Scale on curves is in centimeters; normal is zero.

CURVE II. Two cells in circuit; also shunt. Nickel-plated electrodes. When precaution is taken to have constant pressure on electrodes (no involuntary relaxation of grip) the curve is constant and shows no slope. Rhythmical breaks in the curves show minute intervals.

Sommer's attitude towards the galvanic phenomenon is rather negative. He ascribes the galvanic deflections to contact-effects between the skin and the electrodes, also to changes in the resistance of the epidermis. An involuntary increase or decrease of pressure on the electrodes would change the points of con-

CURVE III. Two cells and shunt in circuit. Electrodes put on hands passively so that the pressure of electrodes on hands was constant. There is no fall, but one continuous line with no deflections present.

CURVE IV. No cells and no shunt in circuit. The curve shows galvanometric variations due to variations of pressure and of changes of involuntary grip. The maximum variation is more than 12 cm.

tact and skin-resistance thus giving rise to galvanometric variations. It is clear that Sommer does not regard the galvanic phenomenon as the effect of processes taking place in the or-

ganism itself. The galvanic perturbations according to Sommer are rather of a purely physical character and depend on the extent of surface-contact and changes of skin-resistance. Sommer's work must certainly be taken into consideration before one can establish a definite relation between psycho-physiological processes and galvanometric deflections. The usual method of most investigators, namely, the employment of metal electrodes on which the palms of the hands rest, may lend itself to such an interpretation and therefore the galvanic reaction is really not established until that objection is obviated. Jung and Ricksher do not meet Sommer's objections when they say: "That the changes in resistance are not due to changes in contact, such as pressure on the electrodes, is shown by the fact that when the hands are immersed in water which acts as a connection to the electrodes the changes in resistance still occur. Pressure and involuntary movements give entirely different deflections than that which we are accustomed to obtain as the result of an affective stimulus."[1] This rejoinder is not valid as we shall see further on when we discuss the various artefacts to be avoided in order to establish the galvanic reaction.

Binswanger in his extensive study of the galvanic phenomenon does not differ in his technique from that generally employed by Jung and his collaborators with whom he also agrees in his conclusions as to the nature and causation of the galvanic phenomenon. He agrees with Tarchanov that the cause of the galvanic phenomenon is the secretions of the skin "Es scheint mir in Uebereinstimmung mit Tarchanoff und trotz der Ausführungen Stickers das es sich hier im wesentlichen um Sekretionströme der Haut (Schweissdrüssen) handelt."[2]

In a series of experiments Sidis and Kalmus[3] have affirmed the fact of the 'galvanic phenomenon' in relation to certain psycho-physiological states and have shown by various experiments that contact effects as well as skin changes and circulatory disturbances can be fully excluded as the causes of the phenomenon under investigation. Moreover, the same investi-

[1] *Op. cit.*

[2] *Op. cit.*

[3] Sidis and Kalmus, 'A Study of Galvanometric Deflections due to Psycho-physiological Processes,' PSYCHOL. REVIEW, Sept., 1908, Jan., 1909.

gators have demonstrated that what may be called the galvanic reaction has nothing to do with lowered resistance, whether bodily or cutaneous, produced by psycho-physiological processes; they have proven that resistance can be excluded, that the phenomenon is entirely a function of an electromotive force brought about by the action of the psycho-physiological processes set up by various external or internal sensory stimulations. To quote from the original contribution: "Our experiments go to prove that the causation of the galvanometric phenomena cannot be referred to skin resistance, nor can it be referred to variations in temperature, nor to circulatory changes with possible changes in the concentration of the body-fluids. Since the electrical resistance of a given body depends on two factors — temperature and concentration — the elimination of both factors in the present case excludes body-resistance as the cause of the deflections. Our experiments therefore prove unmistakably that the galvanic phenomena due to mental and physiological processes cannot be referred to variations in resistance, whether of skin or of body. *Resistance being excluded the galvanometric deflections can only be due to variations in the electromotive force of the body.*"[1] Our present work has in various ways amply corroborated the same conclusion and has definitely determined the actual cause of the observed galvanometric deflections concomitant with some psycho-physiological processes.

III.

From the history of the subject we may now pass to a discussion of the technique of the experiments. The usual technique of most of the investigators is very simple. In connection with a D'Arsonval galvanometer one or two cells are introduced into a circuit terminating in two metal electrodes, zinc, copper, brass or steel in case of hypodermic needles. The galvanometer, being shunted, the subject places himself across the electrodes usually putting one hand palm downwards on each of the two electrodes, thus closing the circuit.

Jung describes his apparatus as follows: "The author (Dr. Veraguth) conducts a current of low tension (about two volts) through the human body, the places of entrance and exit of

[1] *Op. cit.*

the current being the palms. He introduces into the circuit of the current a Deprez-D'Arsonval galvanometer of high sensibility and also a shunt for lowering the oscillations of the mirror. I add to the scale a movable slide with a visiere. The slide pushed forward by the hand always follows the moving mirror reflex. To the slide is fastened a cord leading to a so-called ergograph-writer which marks the movements of the slide on a kymographic tambour fitted with endless paper upon which the curves are drawn by a pen point. For measuring the time one may use a 'Jacquet chronograph' and for indicating the moment of irritation (stimulation?) an ordinary electric marker."[1] In their more detailed study Jung and Peterson give the following account of the apparatus employed by them: "The mirror galvanometer of Deprez-D'Arsonval; a translucent celluloid scale divided into millimeters and centimeters with a lamp upon it; a movable indicator sliding on the scale and connected by a device of Dr. Jung with a recording pen writing upon the kymograph; a rheostat to reduce the current when necessary; and one, sometimes two, Bunsen cells. The electrodes generally used are large copper plates upon which the palms of the hands rest comfortably or upon which the soles of the feet may be placed."[1] Ricksher and Jung used the same apparatus with 'brass plates as electrodes upon which the test-person places his hands and completes the circuit.'

It will be observed that most of the investigators used electrodes, generally metal ones, without any precautions as to the traps encountered and to the artefacts produced. To avoid all those pitfalls and thus establish the galvanic reflex on a sure basis of facts Sidis and Kalmus employed the following technique:

"In a series with a battery was a sensitive galvanometer across which the subject placed himself, thus closing the circuit. The battery was a single cell giving a constant electromotive force of about 1 volt which was sometimes replaced by a thermo-element giving only a few millivolts, and sometimes entirely removed from the circuit. The galvanometer was of the suspended coil, D'Arsonval type and of extreme sensitiveness.

[1] *Op. cit.*

The deflections were read by means of a beam of light deflected from a mirror attached to the moving coil of the instrument, to a telescope with a scale. A deflection of 1 cm. on the scale corresponded to less than 10^{-9} ampere through the instrument. This extreme sensitiveness was too great for many of our early experiments so that a resistance R which could be varied to reduce the sensitiveness to any desired degree, was shunted around the galvanometer.

"The electrodes were glass vessels of about 4 liters capacity nearly filled with a strong electrolyte, as for instance a concentrated solution of NaCl. Into these vessels large copper electrodes of about 500 cm.^{2} area were permanently placed. The circuit was completed by placing the hands, feet, etc., one into each electrode solution.

"The galvanometric deflections may be due to changes in the resistance at the electrodes brought about by such purely physical causes as motion or muscular contractions of the hand, stirring of the electrode fluid or similar incidental secondary effects. In order to eliminate the possibility of such effects it was necessary to devise such electrodes that the current through the circuit should, within very wide limits, be independent of the position of the hands. The possible sources of error at this point which would change the effective surface of the hands are twofold — (1) due to the variation of the liquid level at the wrist, and (2) due to movements of the hand as a whole. The following device was used to overcome those difficulties. The wrist was covered with shellac for a length of several inches, so that the free liquid-surface of the electrode was always in contact with shellac. The shellac was covered by a layer of paraffin, though a moderate coating of shellac alone was such a good insulator that the electrode resistance became independent of the height of liquid on the wrist. In addition to this the hand was put in splints in such a manner that only a small fraction of the skin was covered, so that no appreciable muscular contraction of the phalanges could take place (the same skin-area being washed by the liquid electrodes). If now a stimulus was given which aroused an emotion or definite affective state in the subject, a marked galvanometric deflection was observed."

After excluding resistance, both of skin and body, circulation, skin secretions Sidis and Kalmus give, as the result of their investigations, the following summary: "*Our experiments thus clearly point to the fact that active physiological, sensory and emotional processes, with the exception of ideational ones, initiated in a living organism bring about electromotive forces with consequent galvanometric deflections.*"[1]

In our own technique we at first closely followed that of Sidis and Kalmus with the only difference that our subjects were not human beings, but rabbits and frogs. In the course however of adaptation of the technique to the special conditions of experimentation as well as in our efforts to eliminate complicating factors and have the results free from artefacts the technique has become substantially modified. We shall give an account of these important modifications as we proceed with the exposition of the results of our investigation.

IV.

Before however we give an account of our technique and its gradual modification in its adaptation to the needs of the experiments in hand, it is well to give a brief review and possibly a short discussion of the main artefacts to which this work is subject. In carrying on experiments on such an intricate problem where the factors, physical, physiological and psychological, are so numerous and complex special care must be taken to avoid the artefacts which are sure to creep in and vitiate the results. The first requirement in such work is simplification of the technique so as not to introduce conditions which are apt to complicate matters and obscure the possible solution of the problem. The conclusion arrived at by Sidis and Kalmus, differing widely from that arrived at by earlier investigators, namely, that the galvanic phenomenon is not due to resistance, whether of skin or of body, but to an electromotive force, helped us materially in the simplification of the conditions of the experiments, a simplification which those investigators have afterwards adopted in the course of their work. This simplification consists in the discarding of the electric batteries introduced into the circuit. The introduction of electric cells is apt to mis-

[1] *Op. cit.*

lead the investigator from the very start, inasmuch as he is unconsciously led to postulate that the resultant galvanometric deflections are due to resistance. He assumes that the only electromotive force present is the one derived from the cells and which is therefore constant. Since the strength of the current C is $= E/R$ and as E or the E.M.F. of the cells is constant the variations of the current C which give rise to the deflections of the galvanometer must necessarily be due to variations of R, that is, of resistance. Since resistance R consists of two elements (1) resistance r_1 of the physical system, cells, electrodes and galvanometer, and (2) resistance r_2 of the body; since again resistance r_1 is constant, it necessarily follows that the galvanometric deflections are due to variations of resistance of the elements or tissues of the body. It is this faulty technique of using cells from which the E.M.F. is supposed to be derived and passed through the body of the test-person that has given rise to the unproved assumption that the variations of the current which produce the galvanometric deflections are due to lowering of bodily or tissue-resistance.

It is clear, if we make no assumptions, that in the formula E/R the variations may take place either in E, or in R, or in both. In other words, the unbiased experimenter realizes at the start that he deals here with electromotive forces and resistances which either alone, or both, may participate in the causation of the observed galvanometric deflections. While therefore it is a fundamental fallacy, a *petitio principii* as it is termed in logic, to make at the outset the unwarranted assumption of ascribing the galvanic effects to variations of only one of the factors, namely, resistance, it is on the other hand a serious error of technique to use cells in the circuit and thus complicate unnecessarily the conditions of the experiment. The introduction of more elements, of cells and shunts, brings in more electric forces and resistances into the circuit and thus only helps to complicate and obscure the investigation of an intricate subject. We must remember that the first requirement of an experimental work is not complication, but elimination and simplification.

If we examine more closely the conditions of experimenta-

tion of the various investigators, we find that one of the most serious artefacts results from the employment of metal elec-

CURVE V. *V.* (*a*) Copper electrodes; no cells and no shunt in circuit. The electrodes were put on the hand *passively* so that there was no alteration due to *active* pressure. (*b*) Copper electrodes under same conditions of circuit. Hands put *actively* on the copper electrodes. V_I. Show passive (*a*) and active (*b*) pressure of platinum electrodes. V_{II}. Show passive (*a*) and active (*b*) pressure of tinfoil electrodes.

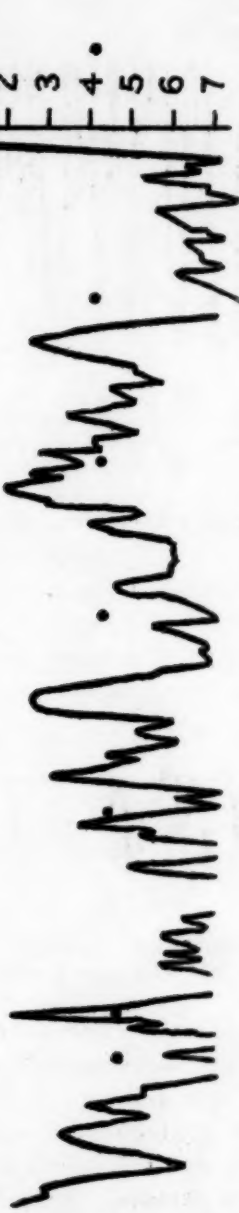
trodes, such as copper, zinc, nickel, brass and steel in direct contact with the fluids of the palmar surfaces of the hand. Calomel-mercury electrodes present similar artefacts on account

of the impurities giving rise to currents with sudden and often ceaseless fluctuations of the mirror-galvanometer thus causing extensive artefacts seriously impairing the value of the results. One cannot help realizing the full force of Sommer's objections that under such conditions numerous variations of contact are brought about, variations which in themselves are amply sufficient to account for the observed galvanometric perturbations. The results are at any rate vitiated and totally obscured. Under such conditions of experimentation galvanometric deflections cannot possibly be correlated with psycho-physiological changes. It can also be shown that in the use of metal electrodes the galvanometric deflections obtained when the hands are placed on the electrodes differ widely from those obtained when the same electrodes are put (passively) on the hands (see Curves V, V_1, V_{11}).

An important source of error is the employment of polarizable electrodes. The physical currents induced by polarization give rise to so many electrical variations and consequent galvanometric deflections as to destroy the scientific value of the results. The fluids of the palmar or of the skin surfaces in contact with the polarizable metal electrodes initiate a number of currents which ceaselessly give rise to large sudden deflections of the mirror-galvanometer. In cases where we have all those conditions combined, namely, increased or decreased surface-contact and pressure accompanied with changes of polarization we can realize how unreliable and untrustworthy the final results are. The current view that the galvanometric deflections are due to skin-effects is quite in accord with the artefacts of the experiments, since under such conditions the main galvanometric deflections do occur under the various influence of skin-effects. As long as the experiments are conducted under such faulty conditions and are beset with such serious artefacts not only is it vain to expect a correct view of its causation, but even the very fact of the correlation of psycho-physiological processes and galvanometric deflections cannot be established with any degree of certainty. The claim of Jung and his collaborators that "when the hands are immersed in water which acts as a connection the changes still occur" is in itself beset with many errors. In the first place, if the liquid is put in two different

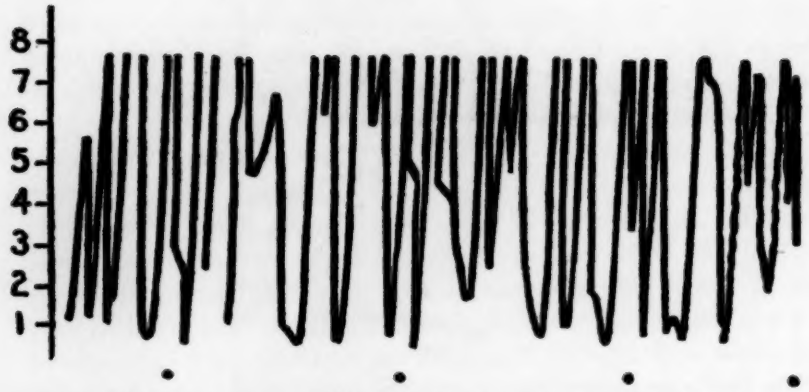
vessels, the liquid must be of the same concentration and of the same temperature, otherwise we get deflections due to difference of temperature and concentration; then again the least change of level of the liquid will change the level at which the electrodes are washed which will produce new currents. At the same time the change of level of the liquid will change the area of the skin washed and will once more initiate currents. Then, again, the wires and metal plates become polarized and additional currents supervene. The artefacts are here so numerous that to obtain any results is almost hopeless. Sidis and Kalmus who worked with liquid electrodes had to contend with all those difficulties and could only circumvent and overcome them with constant vigilance for artefacts and painstaking precautions such as the careful use of pure or distilled water of the same temperature, the use of shellac and paraffin as well as splints for the hands. The following photographic curves will give one a clear idea of the ceaseless play of currents and hence of the artefacts met with in the use of polarizable metal

CURVE VI. Brass electrodes without cells. Electrodes held in the hands. Maximum deflection is more than 14 cm.



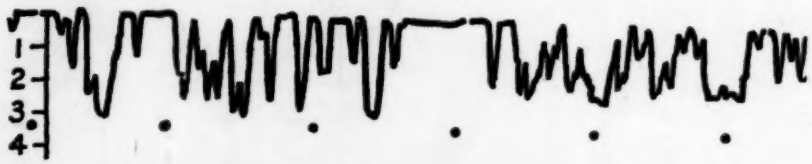
CURVE VII. Copper electrodes (plates) in two vessels filled with water. Hands inserted into the vessels. Two cells and shunt in circuit.

electrodes or of liquid electrodes when the necessary precautions are not taken.



CURVE VIII. Same condition of liquid electrodes but without cells and shunt in circuit. Disturbances of level of liquid and slight restlessness of hands. Maximum deflection is more than 8 cm.

When working with hypodermic electrodes the effects of polarization should be specially taken into consideration. Steel or iron being impure becomes easily affected chemically, thus giving rise to currents with large variable galvanometric deflections. The following photographic curves obtained with steel electrodes inserted into the skin of a rabbit's abdomen bring out clearly the effects of polarization:



CURVE IX. Steel electrodes inserted under skin of abdomen of rabbit. No cells, no shunt. Maximum deflection about 3 cm.

It becomes clear from what we have said how cautious one has to be and with what numerous difficulties one has to cope in the investigation of this subject. Considering then the difficulties and numerous artefacts we had to contend with it may be of interest to point out the development of our technique. As we have already mentioned the fact our work links on to that of Sidis and Kalmus and naturally our technique was the same as theirs. These investigators started with the usual pro-

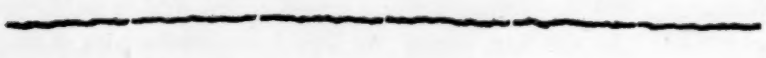
cedure, common to all earlier investigators, of introducing cells into the circuit. Unlike however other investigators they did not start with the tacit assumption of regarding the observed galvanometric deflections as due to variations of the factor of resistance alone. They were on the lookout for variations both of electromotive forces and resistance. Since the trend of their experimentation was clearly in the direction of electromotive forces and towards the total elimination of resistance as a factor in the galvanic perturbations, they finally in their later experiments completely dispensed with the cells and superimposed electromotive forces derived from outside sources and worked with the electromotive forces manifested by the organism under the influence of external stimulations. Such a procedure is essential as it deals directly with the phenomena under investigation. We followed the same procedure and discarded the cells. The physical system of the circuit was thus greatly simplified. Moreover, we decided to work on animals instead of test-persons who are by no means favorable subjects for experimentation. Animals present us with great scope for experimentation, for surgical operations, for the injection of various drugs and thus afford opportunities for the study of the causation of the galvanic phenomenon and allow the exclusion of the various complicating factors not concerned in its production.

Now in our experiments with animals, rabbits and frogs, we found that the technique of Sidis and Kalmus had to be further modified. In the first place the liquid electrodes with shellac, paraffin and splints proved inadequate as the hairy legs of the rabbit did not quite lend themselves to such manipulations. Shaving the hair was not satisfactory, taking it off chemically produced an undesirable inflammation unfavorable to the purpose of our experiments. Besides, the liquid-electrodes proved unsatisfactory as it was difficult to restrain the rabbit from agitating the liquid and sometimes spilling the contents of the vessels, thus changing the levels of the liquid with its consequent large galvanometric deflections. The technique was defective, because we had not only to watch the deflections, but also the rabbit, the fluid, the vessels and the wires. Another objection to liquid-electrodes is the fact that they do not elimi-

nate skin-effects which, as it has been demonstrated, are not concerned in the causation of the galvanic reaction. We were therefore forced to give up liquid-electrodes and in order to eliminate the skin, we had to fall back on hypodermic electrodes. This procedure not only considerably simplified the conditions of experimentation, but it also, at one stroke, so to say, greatly simplified our problem, since we thus got rid of the factors of pressure, increased and decreased contact-area and of all the disturbances that might be ascribed to the action of the sudoriferic or sebaceous glands. The simultaneous simplification of method and problem was too important not to take advantage of. Hypodermic electrodes were clearly indicated by the conditions and nature of our work.

It is however one thing to find that hypodermic electrodes are indicated and it is quite another matter to find the proper kind of electrodes. We found that copper, iron, steel, nickel, brass, had to be rejected, because of the ease of polarization giving rise to variable currents with consequent variations of galvanometric deflections (see Curves VI., VII., VIII.).

It was found that platinum is sufficiently pure so as not to become polarized and is therefore well adapted to our purpose. When using hypodermic platinum-electrodes, the galvanometer was found to remain steady as can be seen from the following photographic curve:



CURVE X. Platinum electrodes in abdomen of rabbit. No stimulation; rabbit quiet. No cells: no shunt.

This steadiness of the galvanometer is of the utmost importance, because it gives us a *steady* zero-reading, while in the case of other investigators there is no steady zero-reading, since their galvanometer keeps on ceaselessly varying, thus making the results uncertain and even destroying their value.

Platinum hypodermic electrodes were used by us throughout our work. Our technique thus far was extremely simple: a D'Arsonval type of galvanometer with scale divided into milli-

meters, platinum hypodermic electrodes and a key for closing and opening the circuit.

Focal distance of mirror to lamp is one meter.

Sensibility is 225 megohms.

Period is 9.5 seconds.

The sensibility is given in the number of megohms resistance through which one volt will give a deflection of one millimeter at one meter distance. The period is the time of swing from the maximum deflection to zero.

We found it requisite to take photographic records of the galvanometric deflections. We shall give a detailed description of the apparatus and its complete outfit in its proper place.

V.

The animal was put on an animal board and kept quiet, while the hypodermic electrodes were inserted into the body, usually well under the skin or through a muscle. We may now pass to the experiments. We quote a few experiments selected from our laboratory notes:

Experiment I. — Live rabbit; hypodermic platinum-electrodes inside of thigh.

	cm.
Galvanometric zero reading before closure of circuit	24
Galvanometric reading after closure of circuit	27
Deflection gradually diminishes and in 4.5 minutes returns to	24
Circuit open	24
Circuit closed	24

Opening and closing the circuit did not change the galvanometric zero reading.

	cm.
Circuit closed, galvanometric zero reading	24
Stimulus, pinch, galvanometric reading	23.95
	23.90
	23.85
	23.80
Galvanometer returns to	23.85
	23.90
	23.95
	24

Experiment II. — Same live rabbit; hypodermic platinum-electrodes inside of forelegs.

	cm.
Galvanometric zero reading before closure	24
After insertion of electrodes and closure of circuit galvanometric reading	27
After a period of 4 minutes galvanometric reading	24
Galvanometer stationary at	24
Stimulus, sharp snap on nose; galvanometric deflection	24.10
	24.20
	24.30
	24.40
	24.50
Galvanometer returns to	24.40
	24.30
	24.20
	24.10
	24

Experiment III.

	cm.
Galvanometric reading; circuit open	24
Galvanometric reading; circuit closed	24
Stimulus, series of sharp snaps on nose; galvanometric reading	24.10
	24.20
	24.30
	24.40
	24.80

Galvanometer then returned to its original zero reading.

	cm.
Another series of sharp snaps given to the nose after rabbit had rest brought galvanometer reading to	24.80
A further series of snaps did not increase galvanometer deflection; galvanometer reading remained stationary at	24.80
After a few minutes galvanometer returned to original zero	24

Experiment IV. — New fresh rabbit. Hypodermic electrodes inserted in forelegs.

	cm.
Zero reading; circuit open	24
Galvanometric reading; circuit closed went up to	27
Galvanometer returned and remained stationary at	24
Stimulus, prick; galvanometric deflection	24.10
	24.20
	24.30
	24.40
	24.50
	24.60
	25

Galvanometer gradually returns to original zero..... 24
A series of prick-stimuli given immediately after gave galvanometer deflection..... 24.10
24.20
24.30

More stimulation gave no further deflection.
Galvanometer gradually returns to 24

We must mention here one important point. Every time the platinum electrodes were taken out to be inserted again, whether in a new fresh animal or into the same animal, they were sterilized on a flame and thus purified from extraneous matter. This was the procedure in all our experiments.

To return to our work:

Experiment V. — New fresh, live rabbit.

	cm.
Circuit open; galvanometric reading.....	24
Circuit closed; galvanometric reading	27
After a few minutes galvanometric reading.....	24
Ammonia applied to rabbit.....	24.10
(Rabbit moved slightly.)	24.20 / 24.30
Galvanometer returns to.....	24
Ether given to rabbit.....	24.10
	24.20
	24.30
	24.40
	24.50
Galvanometer returns to.....	24
Ether continued.....	24.10
	24.20
	24.30
	24.40
	24.50
Galvanometer began to return to	24.40
	24.30
At this stage rabbit moved, galvanometric deflection.....	24.40
	24.50
	24.60
	24.70
Galvanometer returned to.....	24.20
Rabbit moved, galvanometric deflection to.....	24.50
Galvanometer returns to.....	24
Every time rabbit moves; galvanometric deflection rises to	24.50
Then returns to.....	24
Rabbit moves again; galvanometric deflection to.....	23.50
Rabbit quiet; galvanometer returns to.....	24

Rabbit completely narcotized; galvanometric reading... 24
Stimulations, such as pricks, snaps, ammonia produce no effect; galvanometer remains unaltered; galvanometer at zero reading..... 24

When rabbit came out of narcotic state the galvanometric deflections under various stimulations were the same as before narcotization:

	cm.
Galvanometric zero-reading, circuit open.....	24
Galvanometric zero-reading, circuit closed.....	24
Stimulus, prick.....	24.10
	24.20
	24.30
	24.40
Galvanometer then returned to.....	24

Out of the many experiments carried out on frogs we take one series as typical of many others.

Experiment VI. — Live frog. Platinum electrodes inserted into each thigh.

	cm.
Circuit open, galvanometric reading.....	24
Circuit closed, galvanometric reading.....	24.40
After a few minutes, galvanometric reading.....	24
Closed and opened circuit several times, galvanometer at	24
Abdomen hit a few times, galvanometer reading to.....	24.05
	24.10
	24.15
	24.20
Galvanometer then returned to zero-reading.....	24
Frog struggled; galvanometric deflection to.....	23.90
	23.80
	23.70
	23.60
Galvanometer then returned to.....	24
Hitting abdomen sharply a few times; galvanometer reading to.....	25
Galvanometer returned to.....	24
Burn (frog struggled); galvanometer reading to.....	23.60
Returned to.....	24
Acetic acid (stimulus); galvanometer reading to.....	24.50
Returned to.....	24
Alcohol injected into mouth of frog; galvanometer reading to.....	23.90
	23.80
	23.70
Galvanometer returned to.....	24

Experiment VII.

	cm.
Strychnine injected into lymph-sac of frog; from zero reading	24
	24.05
	24.10
Galvanometer returned to	24

	cm.
Galvanometer at	24
Stimulus, pinch leg	23.95
	23.90
	23.85
	23.80
Galvanometer returned to	24

	cm.
Galvanometer at	24
Stimulus pinch (frog struggled violently)	25
	26
	27
	28
	29
	30
	31
	31.50
Galvanometer gradually returned to	24

After strychnine took effect stimulation began to give large galvanometric deflections.

	cm.
Stimulus, tapping abdomen slightly, from zero	24
Galvanometric reading	24.90
	24.80
	24.70
	26.50

Even tapping the board produced deflections ranging from 24 to 23.70, to 24.20 and back to 24 cm.

	cm.
Tapping the abdomen of frog sharply, from zero-reading	24
Galvanometric deflection	23
	22
	21
	20
	19
	18.90
Galvanometer back to	24

Frog in convulsions; galvanometer keeps on oscillating from zero-reading 24 cm. to 23.80, to 24, 24.10, to 24.20 and again to 24 cm.

The summary of our experiments with various frogs runs in our note-book as follows; "Frog motionless on board, no deflection. Every time frog moves, galvanometric deflection observed. The extent of the deflection appears to be proportionate to the amount of movement. Alcohol poured on the head of the frog; reaction violent, movements very extensive, large galvanometric deflections. Strychnine 3 drops administered to frog hypodermically. At first frog was quiet, no galvanometric perturbations. Afterwards frog in convulsions, galvanometric deflections amount to 10 centimeters."

The experiments in both species of animals, rabbits and frogs, give us practically the same results. Of course, we should expect to find that in animals so widely different as the rabbit and the frog the extent of the galvanometric deflections would differ under the influence of external stimulations.

At this stage of our work the experiments prove conclusively the following propositions:

1. Every sensory stimulation is accompanied by a corresponding galvanometric deflection.

2. Motor reactions intensify the galvanic phenomenon giving rise to a more extensive deflection.

3. Motor activity is by itself sufficient to give rise to large galvanometric variations, as found in the rabbit and more especially in the frog poisoned by strychnine.

4. The hypodermic electrodes, excluding the effects of epidermis, show that the galvanic perturbations due to external sensory stimulations are not the resultant of skin-effects. In other words, the skin is not concerned in the manifestation of the 'galvanic reaction.'

This conclusion will be established more rigidly by a different set of experiments.

The galvanic reaction being established by our experiments the question may be raised as to whether our experiments give us an insight into the nature of the galvanic phenomenon. Are the galvanometric deflections correlative with psycho-physiological changes induced by external sensory stimulations due to variations of resistance, lowered resistance, or are the deflections due to an electromotive force initiated in the organism

itself by the action of psycho-physiological processes? We may say that our experiments prove conclusively that the galvanic phenomenon is not due to changes of electrical resistance, but to the action of a newly generated electromotive force.

If we scrutinize our experiments more closely, we find that, when the circuit is open, that is, when there is no current, the galvanometric zero-reading is 24 cm. On the insertion of the hypodermic platinum electrodes and closure of circuit there is an initial galvanometric deflection which indicates the presence of a current. This current is due to the slight injury of the tissues produced by the insertion of the electrodes and also due to difference in temperature. After a period of four or five minutes the current subsides and the galvanometer returns to its original zero-reading when the circuit is open and no current is flowing through the system. If we now open and close the circuit, the galvanometric reading remains unchanged at the original zero-reading. In other words, there is no current on opening or closing of circuit. If now, with circuit closed and galvanometric reading at its zero-reading, we prick, pinch, burn, or stimulate the animal in various other ways, we get a galvanometric deflection which can only be brought about by the generation of an electromotive force. It is clear that no change of resistance without an electromotive force can possibly bring about a galvanometric deflection. *Hence our experiments prove conclusively that the galvanometric deflections are not due to changes of resistance, but to electromotive forces.* Since the hypodermic platinum electrodes exclude the effects of contact, pressure and skin, it is obvious that *the galvanic phenomenon can only be due to an electromotive force initiated in the organism itself by the psycho-physiological processes under the influence of external stimulations.*

PART II.

THE CAUSATION OF THE GALVANIC PHENOMENON.

VI.

The problem of the causation of the galvanic phenomenon is highly complex. The physiological processes concerned in the phenomenon may be secretory, coming from skin or other

glandular organs; may be circulatory, due to the blood vessels or lymphatics; may be due to intestinal changes, such as peristalsis; may be nervous, due to the action of the central or sympathetic nervous system, or may be due to tissue-metabolism and activities taking place in the organism, or all of them may participate in the production of the galvanometric deflections brought about by various sensory stimulations. It is by no means easy to disentangle such an intricate mesh of factors. At one stage in our work the experiments seemed to indicate as if peristalsis, with its complex metabolic processes, were concerned in the phenomenon. Thus when the hypodermic platinum electrodes were inserted into the legs or the chest, the initial maximum deflection was about 3 centimeters, the initial deflection when electrodes were inserted in the abdomen was far larger, often amounting to more than 50 centimeters, the ray occasionally getting off the scale. Moreover, constant rapid galvanometric oscillations were present, oscillations not observed when electrodes were inserted in any other place than the abdomen. To give a few of our experiments:

Experiment I. — Live rabbit.

	cm.
Galvanometer zero, circuit open	24
Platinum electrodes in abdomen. Galvanometric deflection off scale returned to 50 and then gradually returning to	24
Deflection to 17; oscillating between 16 and 17.	

Experiment II. — Live rabbit.

	cm.
Circuit open, galvanometer zero	24
Platinum electrodes in abdomen; circuit closed, off scale, galvanometer went to 3, returning rapidly to 7, 8, 9, 10, 11, to 16, 17, and kept on oscillating between 16 and 17.	

Experiment III. — Live rabbit (new).

	cm.
Circuit open, galvanometer zero	24
Platinum electrodes in abdomen. Circuit closed; deflection to 4 cm., then gradually returns to original galvanometer zero	24

Galvanometer keeps on oscillating between 24 and 25 with an occasional large deflection of more than 50 centimeters ascribed to a possible 'rapid transit' of food in the intestinal tract.

An autopsy, however, of the rabbit showed that the intestinal tract was injured in many places by the electrodes giving rise to a number of points of hemorrhage. The results therefore were pure artefacts produced by demarcation-currents or currents of injury having little or nothing to do with the galvanic phenomenon.

Experiment IV. — Live rabbit.

	cm.
Galvanometer zero	24

Platinum electrodes in abdomen, electrodes put so that they should produce no scratches, perforations and points of hemorrhage. Under such conditions the galvanometric deflection when circuit is closed: 26–24.50–24 cm. One fact, however, was of great interest from our standpoint and that was the relatively larger extent of the deflection produced by various stimulations and motor activities of the rabbit, the deflections varying from 4 to 10 and even to 20 centimeters.

We then decided to open the abdomen and find whether there could be directly observed any relation between peristalsis and galvanometric deflections.

Experiment V. — Rabbit given three grms. of urethane. Abdomen opened; intestine exposed; rabbit put into bath of 0.8 per cent. sodium chloride solution.

Circuit open, galvanometer zero..... 24 cm.
Platinum electrodes in sides of abdominal cavity and when circuit closed galvanometric reading 15, 20, 21, 22, 23, 24.
Rabbit struggles; galvanometer 20 and then off scale.
Galvanometer then returns to its original zero-reading, 24 cm.
Galvanometer keeps on oscillating from 24 to 25–25.50–26.

Experiment VI. — After 24 hours dead rabbit in same bath. The oscillation is of the same magnitude from 1–2 centimeters. Platinum electrodes taken out of the rabbit and put in the salt solution alone; the galvanometric deflections were observed to be of the same magnitude, of 2 cm. It was evident that the deflections and oscillations were due solely to the chemical processes and electrical currents generated by them. To clinch the proof the rabbit was taken out of bath and washed with clean water and then electrodes inserted into the abdominal cavity. No further changes were observed. The oscillations

then were artefacts and could certainly not be ascribed to the action of peristalsis. We were then on the wrong track. Still the fact remained that with the electrodes in the abdomen and with all the precautions against injuries and scratches which the autopsies of the rabbits showed to be absent there were undoubtedly relatively far larger deflections than when the electrodes were placed in any other part of the body.

The large abdominal galvanometric deflections which sometimes occur so sporadically gave us good cause to think that we may be here on the track of some of the important factors concerned in the causation of the galvanic phenomenon and that could only be accomplished by a more perfect method of recording the results of our experimentation. What we needed was a record of all the galvanometric deflections that had taken place, — to get, so to say, a continued history of all the changes that had taken place during a certain period. In short, what is requisite is a graphic method and the best graphic method is to get a photographic record which has the advantage of being trustworthy, automatic and continuous. Not only should the photographic records give good continuous curves, but the curves should be for long periods. The apparatus should give us a continuous photographic record at least for a period of two hours. At the same time there should be a chronograph marking time and a marker indicating any important change or time of stimulation. The following is a description of the apparatus used:

The apparatus consists of a Ludwig kymograph K to which is attached a system of two drums D, D_1 by means of two pulleys P, P_1 and belt H. Around the belt there is wound a belt of paper to which a length of six feet of photographic paper may be attached. The galvanometer G is placed on a solid table built to the wall, so that no vibrations should affect it. The source of light is L, a Nernst lamp, which is well covered by a box having a very small narrow vertical slit in it. The pencil of rays coming from the narrow vertical slit is reflected in the mirror of the galvanometer which is placed in the focal distance from a screen S with a horizontal slit which reduces the reflected rays coming from the galvanometer to a point of light. This

ray of light passing through the horizontal slit of the screen falls on the sensitive paper H attached to the belt of paper around the two drums.

For recording the time there is a time-marking device $C_1 C_2 C_3 S_1$ which consists of an ordinary alarm clock with a

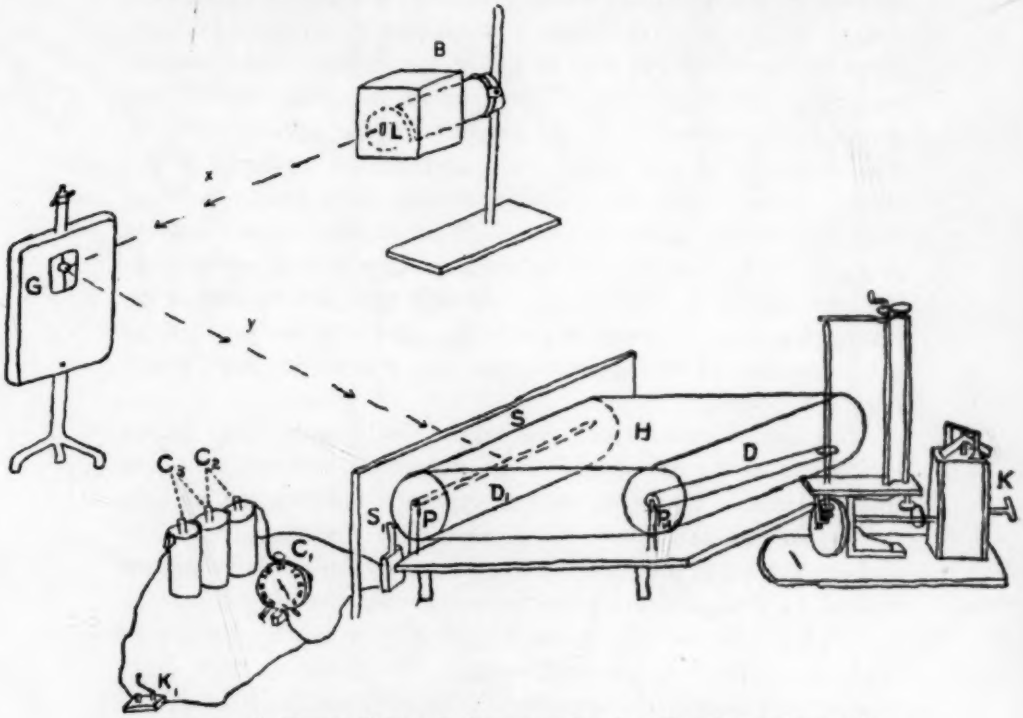


FIG. 1. L, Nernst light; B, box covering L; G, galvanometer; x, y, path of light; S, board with horizontal slit; D, D_1, drums; S_1, telegraphic sounder; C_1, C_2, C_3, clock and cells; K_1, key; H, belt of paper; P, P_1, pulleys; K, kymograph.

prolonged second hand dipping every minute into a cup of mercury thus closing a current coming from three cells. This current is transmitted to a telegraph-sounder S_1 which marks the time on the sensitive paper. By means of a key K_1 the same current is shunted and used to indicate on the revolving sensitive paper the time of stimulation or any other important event taking place during the experiment.

The apparatus fulfilled all the conditions outlined above, —

it gave a long and continuous record of the history of the galvanic happenings. As the photographic record was registered automatically on the sensitive paper we could turn our attention to the rabbit and watch closely any disturbances in the animal. Since the light reflex moving on the brass slit could be easily noticed in the darkened room even from a distance of several meters, it was an easy matter to watch the disturbances taking place in the animal as well as any galvanometric perturbations occurring simultaneously. The time of the disturbances was automatically recorded by the marker on the sensitive paper. The marking of the stimulations and of the changes in the animal placed each event, as it occurred, in its proper position with regard to the galvanic curve. This enabled us to correlate at a glance the disturbances in the animal with the corresponding galvanometric deflections. Armed with this technique we returned with a renewed vigor to the attack of the problem of the causation of the galvanic reaction due to psycho-physiological processes.

In order to come somewhat more closely to the main factor concerned in the production of the galvanic phenomenon it was thought that it might be well to approach the problem by subjecting to test sensitivity itself, especially the affective or the algedonic tone of it which has been demonstrated to be somehow related to the galvanic phenomenon under investigation. In modifying the sensitivity it was hoped that we might possibly be enabled to observe the simultaneous variations of some other factor more closely connected with the various changes of the galvanic reaction.

If again peristalsis is somehow concerned in the causation of the galvanic phenomenon, the modifications of peristalsis should also affect the galvanometric perturbations or possibly that factor which is directly concerned in the causation of the galvanometric deflections.

The modifications of sensitivity, gradual decrease and even total annihilation of sensitivity and then again its gradual increase, are brought about by various anæsthetics, especially by ether and chloroform, while the modifications of peristalsis can be brought about by various purgatives such as magnesium sulphate, oleum ricini, oleum tiglii, etc.

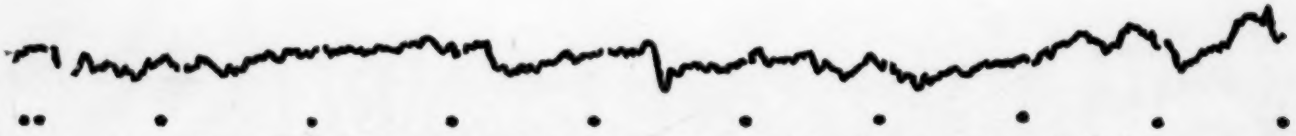
CURVE XI. Platinum electrodes in abdomen of rabbit. First part of curve shows normal, then ether given. Marked deflection during struggle of animal. Rest of curve without deflections, result of anæsthesia. Maximum deflection is about 5 cm. No cells : no shunt.

CURVE XII. Platinum electrodes in abdomen of rabbit. First part of curve normal. Then chloroform given. Marked deflections during struggle. Rest of curve shows no deflections. Rabbit under chloroform anæsthesia. Maximum deflection is about 5 cm. No cells : no shunt.

The foregoing (Curves XI., XII.) are the photographic records taken of the rabbit under the influence of chloroform and ether with or without stimulation.

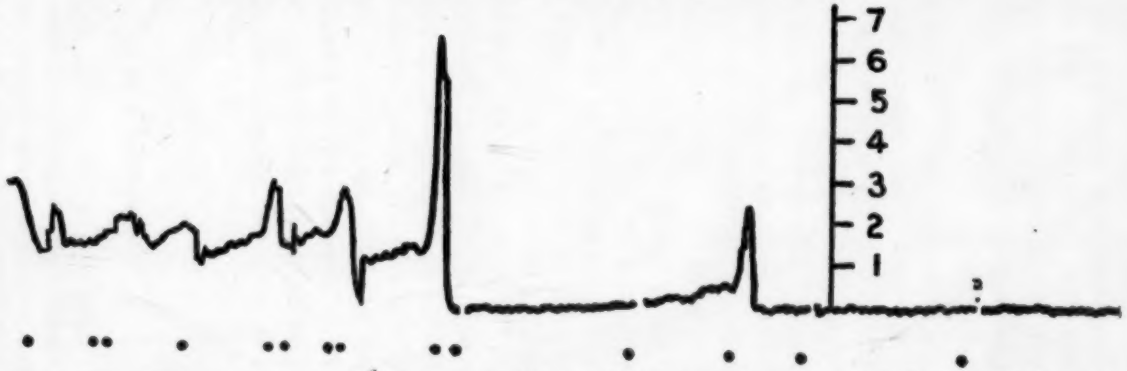
VII.

An examination of the photographic records under anæsthesia discloses the facts of large galvanometric perturbations when the anæsthetic is administered and again when the animal is passing from under the influence of the drug. Stimulations produce more or less marked deflections during the period preceding and following the state of deep narcosis. We notice one important circumstance and that is the fact, that such marked galvanometric deflections are uniformly accompanied by movements and struggles on the part of the animal. When the motor activity diminishes the galvanometric deflections decrease correspondingly and when the animal is quiet the galvanic perturbations completely disappear. The same relation is also observed in the case of the various drugs inducing peristalsis. Peristalsis accompanied by motor activity such as struggles, twitchings, shiverings, convulsions and generally by muscular contractions produce galvanometric deflections which seem to be proportionate to the extent of the observed muscular activity. Where motor activity is absent, although the action of the drug continues with its consequent peristalsis no galvanometric changes can be detected. Thus in the case of defecation which is accompanied by large contractions of the intestinal tract and general condition of straining there are large deflections, while during the intermediate periods of peristalsis, when the animal is quiet no deflections are present. This also holds true even of such cathartic drugs as aloin and croton oil. The curve of apomorphine is especially interesting from this standpoint. The injection of apomorphine into the rabbit does not produce vomiting, but causes continuous shivering and twitchings of almost all the muscles. The result is a corresponding ceaseless fluctuation of the galvanometric deflections. No less instructive is the injection of strychnine which gives rise to twitchings and convulsions with corresponding deflections of the mirror-galvanometer well brought out in the following photographic record:



CURVE XIII. Platinum electrodes in abdomen. Curve of defecation. No cells: no shunt.

CURVE XIV. Platinum electrodes in abdomen. Curve shows deflections under apomorphine injected into rabbit. Apomorphine injected 5 mg. Maximum deflections about 5 cm. No cells : no shunt.

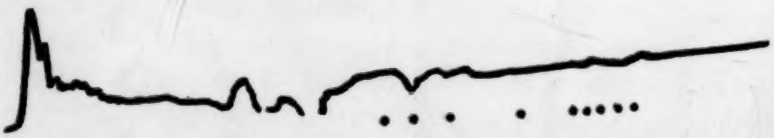


CURVE XV. Platinum electrodes in abdomen of rabbit. Injected strychnine 0.5 mg. Deflections during convulsions. Maximum deflections about 7 cm. No cells : no shunt.

The same relation holds true even in the case of the galvanometric deflections due to various stimulations. Where the stimulation is accompanied with motor reaction there the deflection is manifest, where such reaction is absent the galvanic deflection does not appear. All those facts point to the conclusion that the concomitant motor activity plays an important and possibly a predominant rôle in the causation of the galvanic phenomenon.

This agrees with the work of Sidis and Kalmus who have observed in their experiments that coughing, laughing, sitting, rising, bending arms and muscular activity in general give rise to marked galvanometric deflections. "From these experiments," they say, "it seems that muscular activity of those parts of the body actually forming the circuit bring about galvanometric deflections, while activity of the more remote parts are ineffective."[1] We certainly must take issue with Jung and Peterson in their claim that the galvanometric deflection due to coughing is 'psychic, that is, emotional.' The galvanometric deflection in coughing as well as in like physiological activities is entirely of muscular origin which may or may not be accompanied by an emotion.

That the obtained galvanometric deflection during stimulation and consequent contraction of muscles in the circuit is not the effect of movement of the electrodes inserted in the tissues of the animals can be demonstrated by the experiment of moving the electrodes to which are attached insulated rubber bands. Such movements of electrodes, but with no muscular contraction, give no galvanometric deflections. This is to be seen from the following photographic records:



CURVE XVI. No cells, no shunt. Platinum electrodes in legs of rabbit. Rubber bands attached to electrodes for insulation from touch of hands. Pulling hands and moving violently electrodes produced no deflections. When however a stimulation such as prick is given, the rabbit contracts the legs and a galvanometric deflection of 33 mm. is obtained.

[1] *Op. cit.*

VIII.

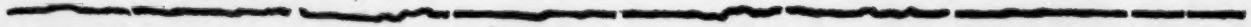
If such relation between motor activity and the galvanic phenomenon exists, it should be demonstrated, after all other possible factors are rigidly excluded, by some crucial experiments.

The first crucial experiment that naturally suggests itself is to restrict the muscular activity of the animal and see what happens to the galvanic deflections, when the animal is stimulated by pinches, pricks, sharp snaps and various other painful agencies. If muscular contraction is concerned in the causation of the galvanic phenomenon, we should find that with their diminution and total suppression the galvanic phenomenon should be correspondingly decreased and even totally abolished. With this end in view we performed the following experiment:

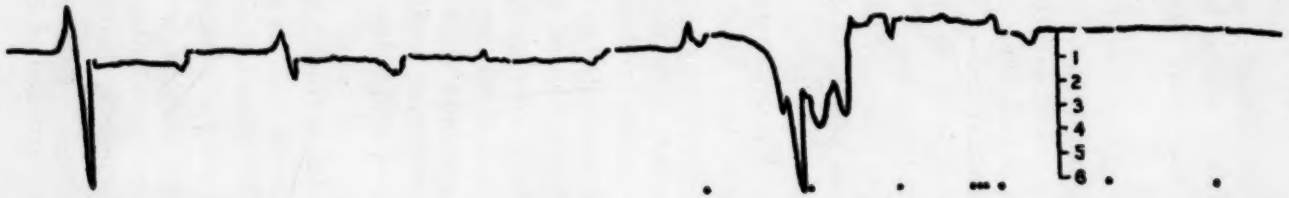
The hind legs of the rabbit were firmly bound so that they could not move. The circuit was closed with the platinum electrodes inserted well into the muscles of the motionless thighs. Under such conditions no stimulations however painful could call forth galvanometric deflections. In other words, with the suppression of muscular action the galvanic reaction disappears. This is clearly demonstrated by the Curve XVI*a*.

With the platinum electrodes in the same position one of the legs was let free to move. When the rabbit was now stimulated the leg, of course, contracted and the galvanic deflections were evident in response to each stimulation. In other words, with the reinstatement of muscular action the galvanic phenomenon once more reappeared as demonstrated by the Curve XVII.

This experiment is crucial, inasmuch as it also excludes all other possible factors, such as secretion, whether of skin or of other glands; it excludes circulation, whether of lymphatics or of blood-vessels and excludes also the action of the sympathetic and of the central nervous system. For if the galvanic phenomenon is due to any, or all of those physiological processes, the galvanic phenomenon should be present under the influence of stimulation, since those physiological processes are not arrested with the restriction of the movements of the limb.



CURVE XVIa. Platinum electrodes into hind legs of rabbit. Legs inmobilized. Rabbit stimulated every minute. No deflections. No cells : no shunt.



CURVE XVII. Platinum electrodes into hind legs of rabbit. One leg free. Rabbit stimulated at intervals of one minute. Deflections with each motor reaction to painful stimulation. Maximum deflections about 7 cm. No cells : no shunt.

Of course, the skin-effects have practically been excluded by the whole course of our experiments, inasmuch as we worked exclusively with subcutaneous electrodes and still obtaining the galvanic deflections in response to various stimulations.

That the skin effects or secretion-currents[1] have nothing to do with the galvanic phenomenon can be further shown by the experiment that when the electrodes are inserted into the skin only, the deflections are made to disappear with the immobilization of the limbs as shown by the Curve XVIII.

In experimenting on the cat similar results are obtained. When the cat is immobilized no sensory stimulations, such as pricking or pinching, can possibly produce any galvanometric deflection. When however the movements of the animal are made somewhat freer so as to make possible muscular contractions the galvanic perturbations under the influence of sensory stimulations become manifest.

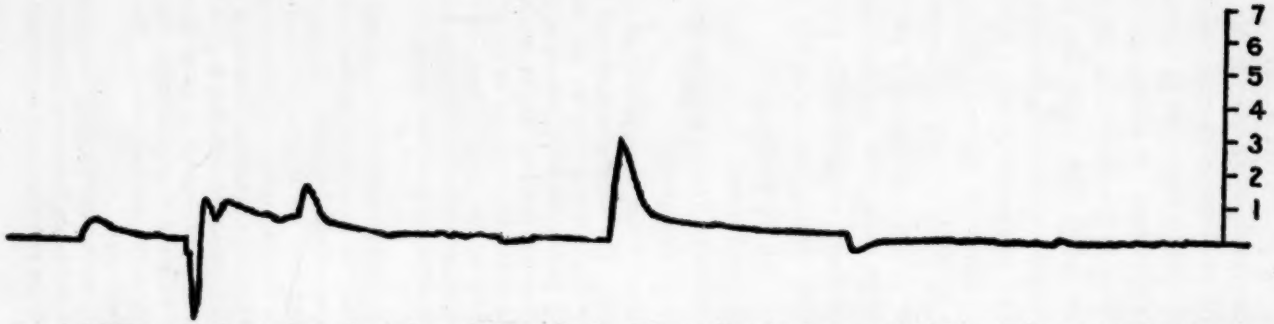
Experiments performed on the frog exclude skin resistance and glandular skin secretion as possible factors in the causation of the galvanic phenomenon.

[1] 'Secretion-currents' are usually ascribed to the physiological activity of the secretory glands. Our experiments, though not final, seem to point to the fact that in 'secretion-currents' we do not deal at all with physiological activities, but with purely chemical processes going on in the end-products of secretion. The chemical processes of the secreted end-products give rise to electrical currents which are regarded as secretion-currents representing the physiological activity of the glands. Such currents however may have little or nothing to do with glandular physiological activity and may be nothing but an *artefact* due to chemical processes going on in the decomposition of the secreted products.

If one of the platinum electrodes is put into the inner surface of the arm-pit rich in glands and the other platinum electrode is put on the shoulder, there is a marked galvanometric deflection. If now we take cotton and saturate it with the secretions from the arm-pit and then let the cotton soak in a small beaker filled with distilled water and immerse one of the platinum electrodes in the beaker and the other platinum electrode in another beaker with pure distilled water, *the galvanometric deflection is found to be of the same order of magnitude and in the same direction as in the experiment on the armpit and the shoulder*. The same result is obtained when the platinum electrode is applied by pressure directly to the saturated cotton. The 'secretion-currents' here are evidently not physiological.

The subject of secretion is highly complicated and cannot be dismissed with a couple of experiments, however suggestive. We shall take up the matter in a separate study on secretion as an accompaniment of psycho-physiological activity.

CURVE XVIII. Platinum electrodes through skin of hind legs. Rabbit immobilized. Painful stimulation given at intervals of one minute; no deflections. No cells: no shunt.



CURVE XVIIIa. Platinum electrodes in legs of strapped cat. Where the animal can react with muscular contractions to stimulations there is a deflection which diminishes and disappears with greater and even complete limitation of muscular movement.

If the frog is put on the animal board, the platinum electrodes put into the muscles and the animal well bound and stretched out on the board so as to arrest muscular activity, the galvanic deflections due to stimulations diminish with the restriction of muscular activity and disappear with the complete arrest of muscular reaction to external stimulation. The galvanic phenomenon remains absent when the platinum electrodes are wound around the freely secreting skin of the frog, or on the inside of the skin layer, or one electrode is put on the outside and one on the inside of the skin. In all such cases, provided the muscular activity of the frog is arrested, the galvanic phenomenon is absent.

If the frog is curarized, thus abolishing the action of the muscles, but not affecting sensitivity, the platinum electrodes inserted into the muscles call forth no galvanic deflection. If the electrodes are now put into the skin or on the inside and outside of the skin layers, no sensory stimulation, however violent, can call forth the galvanic phenomenon.

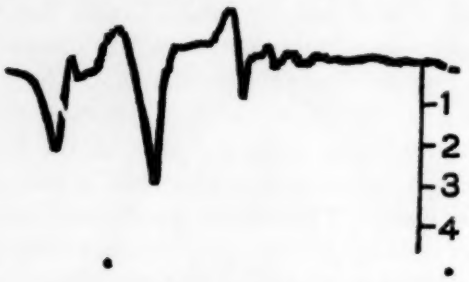
That the glandular secretion has nothing whatever to do with the galvanic phenomenon can be further demonstrated by the following experiment:

The skin of the frog is easily removed from both legs leaving exposed the muscles of the legs into which the platinum electrodes are inserted. When the galvanometer is at zero and remains stationary, the animal, with legs free, is stimulated by sharp pricks or pinches, with each stimulation and concomitant muscular reaction there is a marked galvanometric deflection amounting, in some cases, to more than 20 millimeters. Under such conditions the following characteristic curve is obtained (Curve XVIIIb):

The brain, the spinal cord, the sympathetic nervous system as well as the action of other internal organs, such as liver and spleen, have likewise been *directly* eliminated by us. We plunged our platinum hypodermic electrodes into the tissues of those various organs and found that when muscular contractions were not present the galvanic phenomenon was invariably absent.

Similarly circulation can be directly excluded. Already Sidis and Kalmus excluded circulation as the cause of the

galvanic phenomenon by the use of Esmarch bandages. In the case of animals, such as the rabbit or the frog, it is possible to exclude circulation by ligation of the arteries supplying the



CURVE XVIIIb. Platinum electrodes inserted in legs of frogs. Legs stripped of skin. First part of curve normal Second part shows marked galvanometric deflections under the influence of stimulations (pricks, pinches) concomitant with muscular reactions.

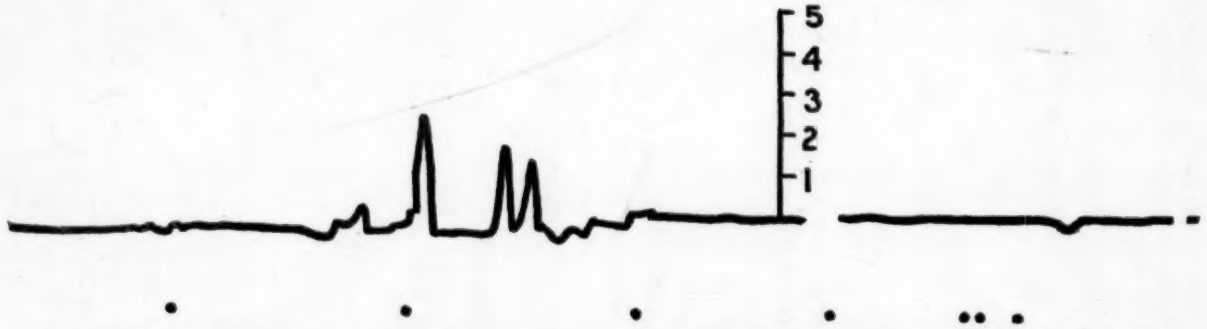
limbs. Under such conditions the galvanic phenomenon still persists showing that blood circulation is not among the causes of the galvanic phenomenon. The following (Curve XIX.) is a photographic record of such experiments:

That the galvanic reaction is entirely muscular can be still further demonstrated by the following experiment:

The sciatic nerves were cut and platinum electrodes inserted into the muscles of the legs. Under such conditions the galvanic phenomenon was absent. No stimulations, however intense and painful given in different parts of the body, could call forth the galvanic phenomenon as shown by the following photographic record: (Curve XX.)

Similar experiments were also performed on frogs and with the same results. With the platinum electrodes in the gastrocnemius of each leg the galvanic phenomenon invariably disappeared when the sciatic nerves were cut. The following curve (Curve XXI.) is a photographic record of the experiment:

The experiment of section of the motor nerves of the legs is also a crucial one, inasmuch as the galvanic phenomenon disappears on the paralysis of muscular activity, although all other conditions, skin secretions, circulation and sensory nerve processes remain unchanged. Moreover, it may be added that



CURVE XIX. Platinum electrodes in left hind leg of rabbit. Left femoral artery ligated. Left leg free. Rabbit stimulated at short intervals of 20 seconds. Marked deflections with each stimulation. Maximum deflection about 3 cm. No cells: no shunt.

CURVE XX. Platinum electrodes in hind legs of rabbit. Nerve supply to both legs cut. Stimulation given at intervals of a minute. No deflections present. No cells: no shunt.

CURVE XXI. Platinum electrodes wound around gastrocnemius muscle of frog. Sciatic nerve cut. Leg free. Frog stimulated at intervals of 20 seconds. No deflections to stimulations. No cells: no shunt.

the galvanic deflections can be reinstated even under conditions of paralysis of motility by passive contraction of the muscles of the leg, as demonstrated by the following photographic record: (Curve XXII.)

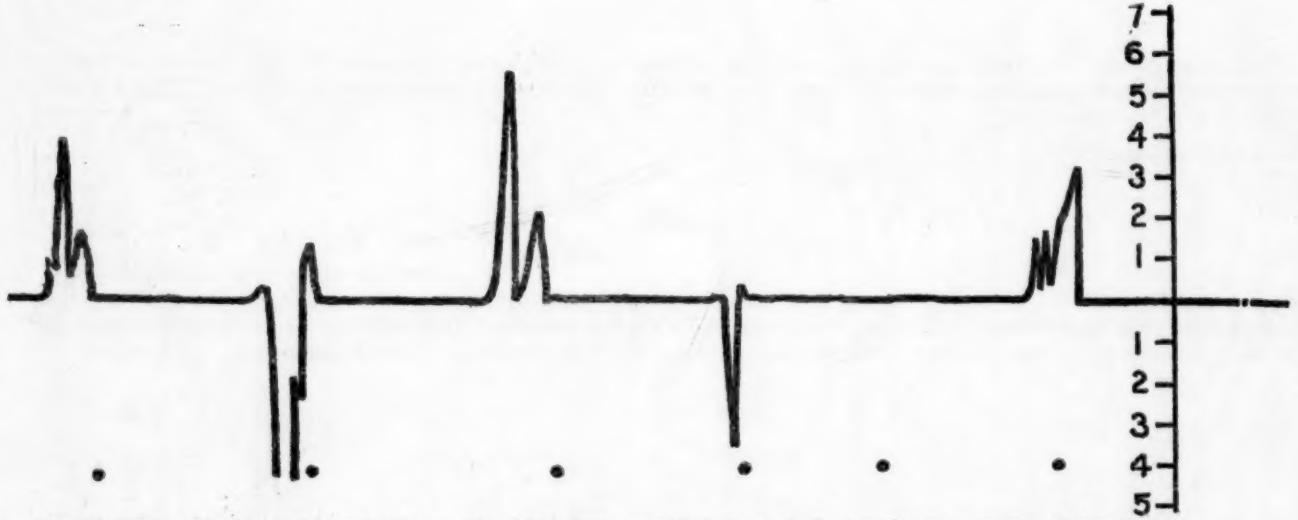
We can now explain the large galvanometric perturbations obtained in the case when the hypodermic electrodes are inserted into the abdominal wall. The animal in all of our experiments was tied on a board so that the extremities were naturally more limited in their movements than the abdomen, which remained free to react to painful stimulations.

We are also in a position to account for the significant fact, present in all of our experiments, namely, that struggles, twitchings and convulsions are followed by large galvanometric deflections. For *our work proves conclusively that the galvanic reflex is a muscular phenomenon. The galvanometric deflections are due to electromotive forces liberated by muscular activity under the influence of affective and emotional states.*

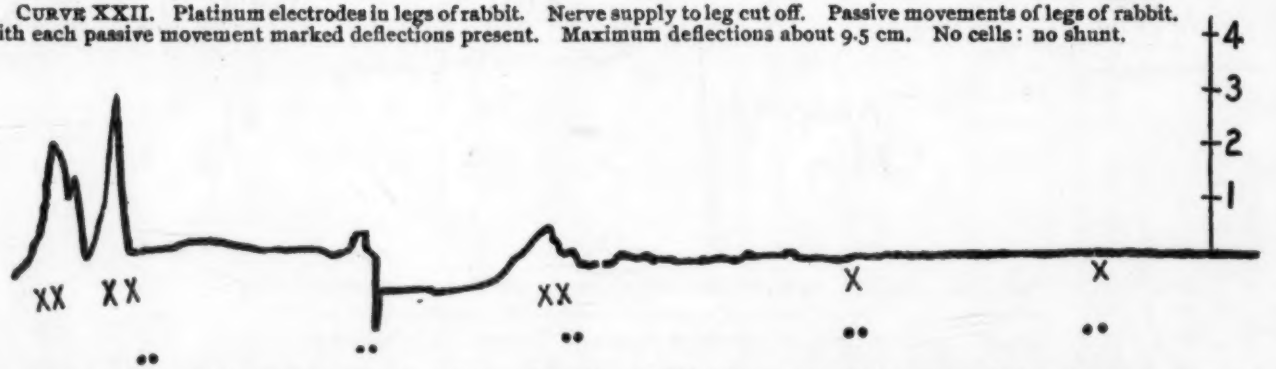
Another crucial experiment is that of injection of curare. It is well known that curare only affects the striped or voluntary muscles leaving all other functions unimpaired. Now when the frog or the rabbit is injected with a dose 2 c.c. of 1 per cent. solution of curare and kept alive by artificial respiration the galvanic phenomenon completely disappears. The paralysis of muscular activity causes this disappearance of the galvanic phenomenon. The following photographic record shows the results of the experiments under the influence of curare: Curve XXIII.

Marked rhythmical deflections are obtained from muscular contraction of heart as shown by Curve XXIV.

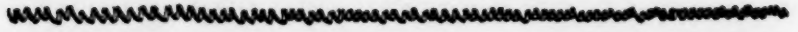
We can now understand the reason of the apparent paradox so puzzling to Jung and Peterson when they say "there are features presented which are as yet quite inexplicable, as for instance, the gradual diminution of the current in long experiments to almost complete extinction, when our ordinary experience teaches



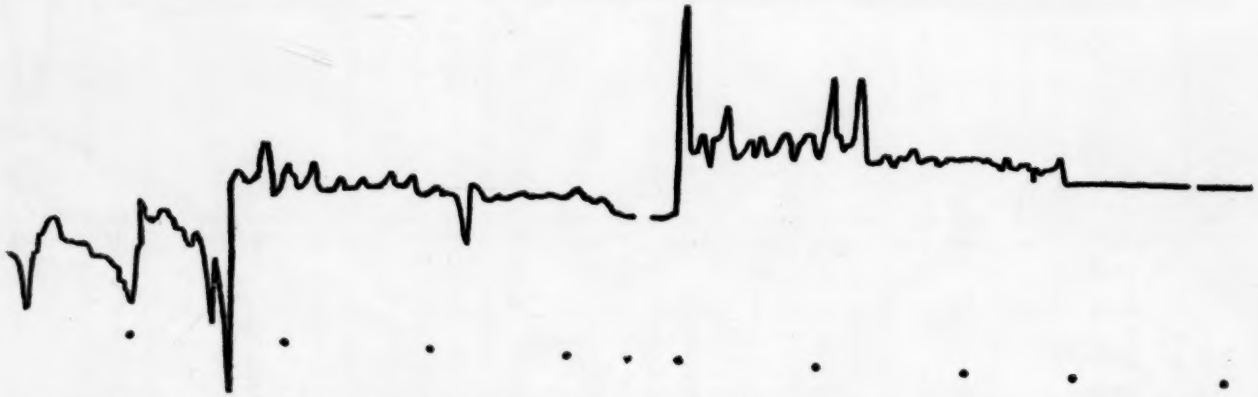
CURVE XXII. Platinum electrodes in legs of rabbit. Nerve supply to leg cut off. Passive movements of legs of rabbit. With each passive movement marked deflections present. Maximum deflections about 9·5 cm. No cells: no shunt.



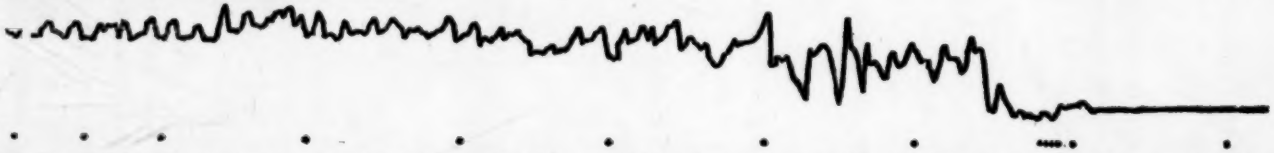
CURVE XXIII. Platinum electrodes in abdomen of rabbit. Rabbit given 2 c.c. of 1 per cent. solution of curare. Stimulation gave no deflections. Deflections are obtained by slight passive movements of legs and by tapping or rubbing abdominal walls, deflections amount to 35 mm. No cells: no shunt. (x) shows stimulation. (xx) shows passive movement of legs.



CURVE XXIV. Platinum electrodes wound around heart of rabbit. Rabbit injected with 4 c.c. of 1 per cent. solution of physostigmine. Deflections are synchronously with the contractions of the cardiac muscle. No cells: no shunt.

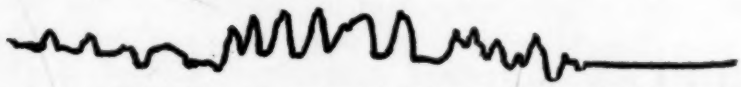


CURVE XXV. Platinum electrodes in hind legs of rabbit. No cells and no shunt. Legs are free. After a normal is taken a series of stimulation of slight touches every 10 seconds is given to the leg of the rabbit. The galvanometric reaction reaches its maximum of 6.5 cm. with violent muscular reaction to subside for a period of 4 minutes, after which the galvanometric reaction once more reaches its maximum and so on.



CURVE XXVI. Platinum electrodes in hind legs of rabbit. Right leg free. A series of hard pricks given to rabbit at regular intervals of 10 seconds. The galvanometric reaction gradually diminishes falling from 30 mm. to about 3 mm. No cells: no shunt.

that resistance should be much reduced and the passing current larger and stronger." The reason why Jung and Peterson find the fact of 'the gradual diminution of the current' so 'inexplicable' is because they have totally misconceived the nature and cause of the galvanic phenomenon. In the first place, we do not deal here at all with resistance, but with an electromotive force. In the second place, the electromotive force generated is muscular in origin. This makes 'the gradual diminution of the current in long experiments to almost complete extinction' an absolute necessity. For it is clear that an electromotive force cannot possibly become stronger and larger 'with continuous use.' That would be against all the laws of physics. With continuous use the muscles become exhausted and with the repetition of the same stimulus a lesser impression is made on the sensory nervous system calling forth a smaller and smaller muscular reaction with its accompanied diminution of electromotive force and consequent decrease of galvanometric deflection. This is demonstrated by Curves XXV, XXVI, XXVII.



CURVE XXVII. No cell, no shunt. Platinum electrodes in legs of rabbit. Legs free. Passive movement of legs every 10 seconds. Curve shows diminution from 20 mm. to 5 mm.

We may say then that all our experiments prove incontestably that the galvanic phenomenon is due to an electromotive force which is muscular in origin.

VIII.

In conclusion we may make the following summary of our results:

1. Galvanometric deflections are brought about by psychophysiological processes (but not by purely ideational processes) under the influence of various stimulations.

2. These galvanic deflections termed by us 'galvanic reactions' are not due to variations of resistance, whether of skin or of body.

3. The galvanic reaction is the *result of variation of elec-*

tromotive forces produced by the psycho-physiological processes set into activity by the agency of external or internal stimulations.

4. The causation of the galvanic reactions cannot be referred to circulation, nor can it be referred to secretory currents, whether of skin-glands or of other glandular organs.

5. The central nervous system and the sympathetic nervous system are alike excluded as factors concerned in the manifestation of the galvanic reaction.

6. *The galvanic reaction is entirely a muscular phenomenon* due to contraction, stretching, straining of the muscular fibers under the influence of various agencies, be they psychic, sensory, physiological, chemical, thermal, electrical or mechanical.

7. The galvanic reaction is chiefly brought about by the muscles within the circuit.

8. Prolonged active peristalsis gives rise to galvanic deflections which are due to the contraction of the muscles involved in the process of peristalsis.

9. The galvanic reaction diminishes and even completely disappears with the repetition of the same kind of stimulation.

10. This fall or complete disappearance of the galvanic reaction with the repetition of stimulation is usually due to a decrease of sensitivity in regard to the same repeated stimulation.

11. The fall however of the galvanic reaction may also be brought about by the action of a prolonged stimulation resulting in a gradual fatigue of the muscles in the circuit.

12. The heart-beat, like the contractions of any of the other muscles, gives rise to galvanic deflections.[1]

We are glad to thank Professor Franz Pfaff, of the Pharmacological Department of Harvard Medical School, for the many opportunities and courtesies shown us in the carrying out of this experimental work.

[1] The clinical aspect of the galvanic reaction will be considered by us in a separate study.

PERSONAL DIFFERENCES IN SUGGESTIBILITY.

BY PROFESSOR WALTER D. SCOTT,

Northwestern University.

Discussions upon suggestion and suggestibility ordinarily seem much influenced by the older concepts taken from 'faculty' psychology. In that former time observation, for instance, was assumed to be an unanalyzable and elementary faculty. One person might possess a good power of observation and another a poor one. Individuals of a group could be given some single test and thus classified and given rank as to their power of observation in general. To-day we speak of suggestibility in an analogous fashion. This manner of thought is not confined at all to the laity but finds explicit expression in most of the recent technical discussions of the subject. The statements are made without reservation that children are more suggestible than adults; that girls are more suggestible than boys; that some nations are more suggestible than others; that neurasthenics, psychasthenics and hysterical are peculiarly suggestible; and finally that any particular group of individuals could be definitely ranked according to the degree of their suggestibility.

In an attempt to determine to what extent suggestion is a general faculty and therefore to what extent individuals could be ranked as to the degree of their suggestibility, a single group of individuals has been tested by various methods. The results secured by the different methods were then correlated by the well-known Pearson's formulæ for the coefficient of correlation.

For the most part the methods employed were taken directly from the literature describing methods for testing suggestibility and need no further comment. Two of the methods or devices, however, were, at least in part, new and seem especially well adapted for testing suggestibility.

The first method was one for controlling by suggestion the

sequence of colors in the visual after-image secured from fixating white light.

The subjects were college students who were just beginning their first course in experimental psychology. Many of them were at the time experimenting upon negative after-images for colored papers.

For the experiment upon suggestion each student was taken singly into the room specially prepared to increase the suggestibility for the particular experiment. A mounted spectral chart was demonstrated and the spectral order of the colors committed by the student. The Bradley disk, composed of six sectors, each of a single spectral color, arranged in order, was placed on the color wheel and revolved till a pure gray was secured. A prism was used to separate the rays of white light into the several spectral colors. The student was then instructed that just as the prism analyzed the white light into the spectral colors so an after-image from white light would contain the spectral colors in sequence. He was told that the experimenter was securing data as to the exact time various subjects required for observing in sequence the various spectral colors as they develop in the after-image.

The experimenter sat before a kymograph with a time marker which marked seconds on the smoked paper. The light necessary for his work was not sufficient to add greatly to the general illumination of the otherwise dark room.

The white light for fixation was secured by means of an opening in a screen twelve centimeters square. The subject sat three meters from the screen and by raising his eyes about thirty degrees he looked through the opening and directly into the white skylight.

The subject fixated this white skylight for twenty seconds, then closed his eyes and had them further screened by several thicknesses of black velvet.

At the conclusion of the fixation the experimenter began at once to increase the previous suggestions by such questions as the following: Let me know as soon as the red appears. Report the red as soon as it comes. Is it red yet? Now is it red?, etc. These questions were continued for 20 seconds or until red was

reported, when the same questions were asked for orange, yellow, and so on through the spectral order.

The subject was of course instructed to report whatever colors he saw and to report them the first moment possible. The experimenter recorded on the revolving drum the color reported and the time of the report.

After the subject's eyes had fully recovered from the effect of the after-image, a second and a third trial was made.

In some instances the after-image lasted several minutes but occasionally it would fade before 30 seconds succeeding the first appearance of any color. For this reason we considered only the colors reported for the 20 seconds succeeding the first report of the presence of any color in the after-image.

With conditions such as those under which we worked the normal sequence of the after-image is first a blue, then a green, then red and then finally a blue. The colors are very brilliant and beautiful. The red ordinarily does not appear during the first 20 seconds. Therefore that red which is reported during the first 20 seconds is recorded as due to suggestion. Apart from suggestion an orange would certainly not succeed a red during the first 20 seconds. Any advance in the spectral order beyond red during this first 20 seconds is unmistakably due to suggestion.[1]

Adding together the first 20 seconds in each of the three trials we get a total of 60 seconds in which the effect of suggestion was being measured. One subject reported as follows: First trial — red, orange, yellow, green, blue and violet; second trial — red, orange, yellow and green; third trial — red, orange, yellow, green, blue and violet. This is a total of 16 suggested colors in 60 seconds. The colors reported were not indistinct but vivid and beautiful. In no way did he suspect that the colors were due to suggestion. As a control at a later time we changed the conditions but not in any essential particular except that we instructed the subject that with the new conditions the spectral order would not be secured. In three trials he reported

[1] No adequate data are available indicating the manner in which the sequence of the colors of the after-images for white light is varied by changes in illumination, time of fixation, etc. The writer contemplates the securing of such data.

the normal sequence, with certain variations as is common to this experiment. We estimated the results of his last trials, namely, those without suggestion, upon the same basis as was used in securing his previous record of 16, and his new record was 1. In one of the three trials the red appeared before the limit of 20 seconds. In no case, however, in the control experiments, did an orange succeed a red.

Of the twenty students tested 3 reported no color due to suggestion and the others ranged from 1 to 16 as is indicated in the following table.

Subject.	No. of Suggested Colors Reported.	Rank in Group of 20.	Times Suggested Heat was Reported.	Rank in Group of 20.
A	16	1	10	5
B	10	2	10	5
C	7	4	9	12
D	7	4	8	15
E	7	4	10	5
F	6	7	9	12
G	6	7	4	18
H	6	7	5	17
I	5	9	10	5
J	3	11½	3	20
K	3	11½	10	5
L	3	11½	10	5
M	3	11½	4	19
N	2	15	9	12
O	2	15	10	5
P	2	15	10	5
Q	1	17	10	5
R	0	19	7	16
S	0	19	9	12
T	0	19	9	12

The same 20 students acted as subjects in an experiment upon the production by suggestion of illusions of heat.

An electric current of 110 volts, direct current, was sent through a bank of lamps and then through a naked wire of high resistance coiled about a lead pencil. The strength of the current passing through the coil was so adjusted that a subject could detect the change of temperature in from 5 to 10 seconds. The lamps were placed on the center of an ordinary sized table and the naked coil was supported a few inches above the table and near its edge. A subject could then sit at the table facing the lamp and grasping the naked coil with two fingers and a thumb. In this position the light of the lamps in the otherwise dimly

lighted room flashed brightly in his face. The heat from the lamps could be slightly felt on the face but was shielded from the coil and the hand grasping it.

The subject was instructed that the experiment was to secure the lower threshold for temperature and that 20 readings would be necessary. He was shown how the current which heated the lamp passed through the naked coil heating it also. He was shown how the wire would gradually increase in temperature till it became appreciably heated. He was told that he was to hold the wire in a particular way and to report the fact as soon as the temperature of the wire appreciably changed.

The procedure of the experiment was well stereotyped. After a warning the signal was given. The stop watch was then started, the electric switch closed, the subject grasped the naked coil and the lamps were lighted. The experimenter then kept one hand on the switch and the other on the stop watch in an attitude of strained attention. At the signal, 'now' from the subject the watch was stopped, the switch opened, the subject removed his hand from the coil and the lamps went out. This was repeated for 10 trials. From the eleventh to the twentieth trial nothing was changed except that the experimenter touched a concealed switch with his knee which shunted the current off completely from the naked coil without in any way reducing the amount of current passing through the lamps. Even when no heat was thus generated in the coil the subject might continue to report the presence of the heat just as regularly as during the first 10 trials.

The experimenter made a rough estimate of the average time for the first 10 trials, and then during the latter 10 trials if the subject failed to report the presence of heat within a time 5 seconds in excess of his previous average, the experimenter removed his knee from the concealed switch and sent the current through the coil. For instance, if during the first 10 trials the subject had reported heat on the average at 7 seconds, then if during one of the latter trials he had not reported heat by the twelfth second, the heat would be sent through the coil, so that ultimately the heat would actually be felt and no suspicion aroused.

As would naturally be expected, some of the subjects re-

ported heat as regularly during the trials from number eleven to twenty as from number one to ten. Some even gradually shortened the time for the second half of the series. Others failed to report heat except when it was actually being generated by the current. Some reported heat occasionally when none was present.

This experiment with heat has many points of similarity with the previous experiment with after-images. Both are concerned with sense-suggestion. In each an attempt is made to change one sensation into another by means of suggestions. In the first an attempt is made to change the normal blue of the after-image to a suggested red and then to other suggested colors. In the latter experiment an attempt is made to change by suggestion a perception or sensation of touch into one of heat. In each the experimenter employs his personality in securing expectant attention through instruction as to what is to be expected. The subjects were experimented upon singly. The time marker in the first and the stop watch in the second set of experiments prompts to hasty reports. Indirect factors enter into each. The sight of the analysis of white light into the spectral colors in the one and the warmth reaching the face from the lamps in the outer are the most significant indirect factors in rendering the suggestions effective. In both experiments the suggested results are fully expected. This was shown by the introspection of the subjects which was secured in each instance. No suspicion was indicated in any of the reported introspections.

The conditions surrounding the experimentation and the psychological factors experimented upon seemed so similar in the two experiments that a fair degree of correlation was anticipated. When, however, the coefficient of correlation was secured from the two sets of data presented in the table on page 150 it proved to be insignificant.

The most natural interpretation of this result is that the suggestibility tested by the one experiment was different from that tested by the other.

Among the psychological factors which differ in the two sets of experiments a few are apparent. Suggestibility in the first case may be dependent upon strength of visual imagery, and

in the second case upon strength of imagery for temperature. If such is the case, then to secure tests upon suggestibility and not upon the relative strength of imagery the experiments would have to be so changed that the demand would be made upon imagery of the same sensorial type, and only those subjects might be included in the group who had relatively equal degrees of strength of this type of imagery.

But perhaps the factor most effective in reducing the coefficient of correlation secured for these two tests lies in the source of the expectancy. In the experiments upon after-images the expectancy was based mainly on the word of the experimenter. The working of the prism and of the color wheel may have been, in some instances at least, negligible factors. In the experiment with heat the word of the experimenter may have been negligible while the experience secured in the first 10 trials with heat may have been, in some instances at least, the sufficient ground for the expectancy. The experiment with after-images may then have been a test of hetero-suggestibility, while the experiment with heat may have been an experiment upon auto-suggestibility. To eliminate this psychological difference in the form of suggestibility being tested it would be necessary to increase the hetero-suggestion in the one or to reduce it in the other. The auto-suggestion in the first could be increased by so modifying the experiment that the subject would have his expectancy aroused by his previous experience. To secure this the subject could be informed that the sequence of the colors in the after-image is blue, green, red and blue. He could then be led to observe the after-images on ten bright days in which the actual order of sequence of the colors of the after-image would be according to his instructions. On his eleventh trial he would expect the same order even though the sky were less bright and therefore another order would normally result. If however he was instructed that the order, blue, green, red and blue was universally secured, and if in addition he had secured that order in ten trials his expectancy would be at least similar to that awakened for the heated wire upon the eleventh trial. In each case the words of the experimenter are corroborated by ten or more instances from the past experience of the subject.

There may be still other psychological factors in addition to differences in imagery and differences in susceptibility to hetero-suggestions and to auto-suggestions which had a part in lowering the coefficient of correlation.

At all events the inference from a study of these two experiments (and others not here described) is that degrees of suggestibility as determined from one test cannot be inferred as holding for suggestibility in general. Before individual *A* can be said to be more suggestible than individual *B* they must have been subjected to many and diverse forms of tests. Otherwise different degrees of suggestibility should be affirmed as present only for the particular form or forms as tested.

Suggestion, like observation, is a general term embracing many psychological processes. We have ceased to speak of people as possessing great powers of observation and instead we specify the particulars in which the power of observation has been shown to be especially good. In studying the personal differences in suggestibility we must adopt a form of expression analogous to the newer forms used in discussing observation. Instead of speaking of high and low degrees of suggestibility in general we are forced to specify the particular in which the degree of suggestibility has been observed.

ANNOUNCEMENT.

THE publishers regret to announce the resignation of Professor J. Mark Baldwin as editor of these publications after sixteen years' activity. The PSYCHOLOGICAL REVIEW was founded by Professors Baldwin and Cattell in 1894. It was successful from the start, and has become the center of several publications covering different types of contributions to psychology. The Review Publications will hereafter be conducted by the present editors of the REVIEW, BULLETIN, and MONOGRAPHS.

Contributions, books, and editorial correspondence may be addressed to any one of the responsible editors.

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